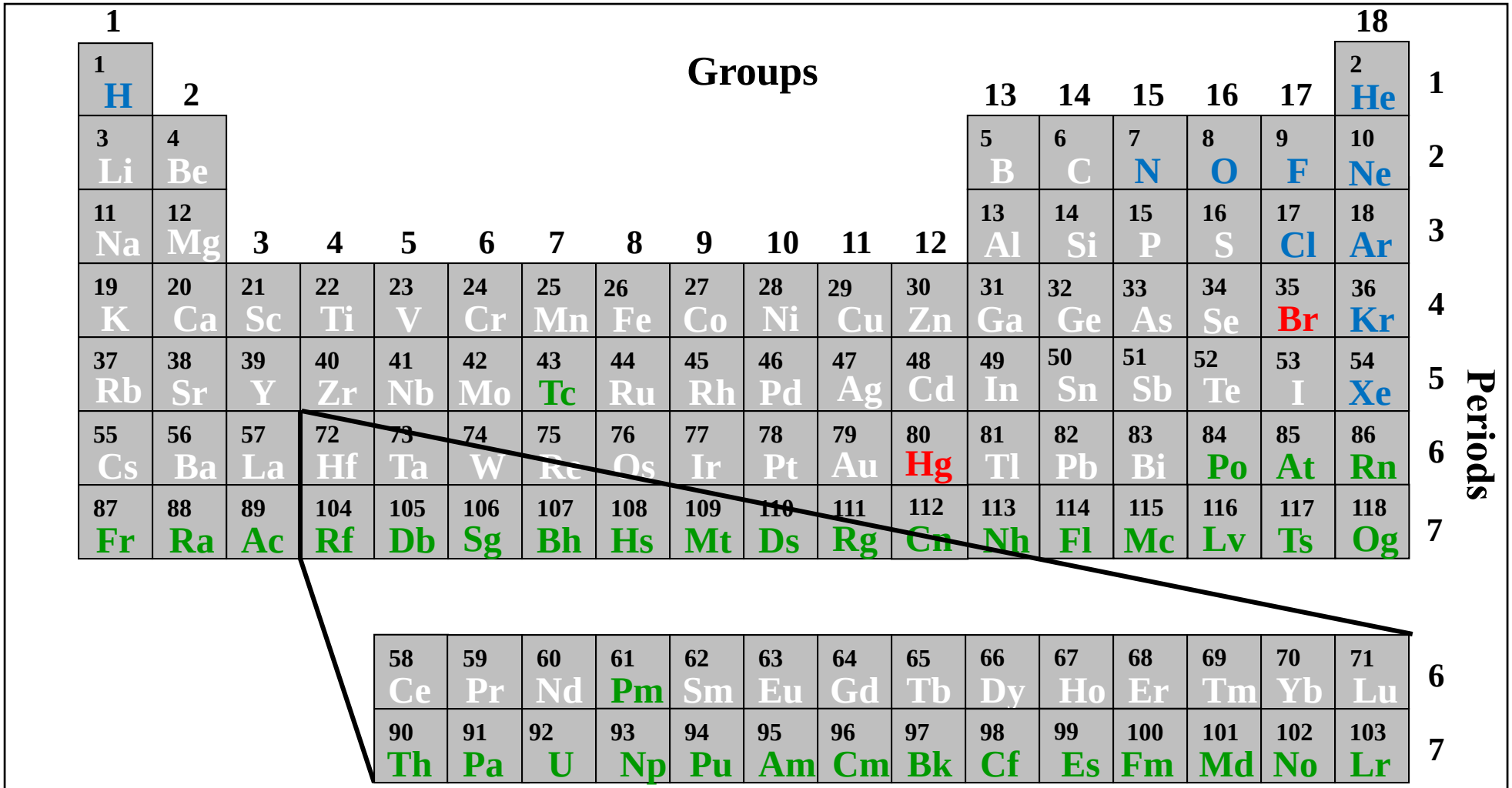
Starting Materials for Solid State Chemistry



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Lithium Li

Li: [He]2s^1

Atomic number	**3**
Rel. atomic mass	**6.941 g/mol**
Melting point	**181 °C**
Boiling point	**1342 °C**
Density	**0.53 g/cm^3**

Chemical composition	**Mineral name**
$LiAl[SiO_3]_2$	**Spodumene**

Starting materials	**Properties relevant for solid state chemistry**
Li (metal)	**hard to handle, prone to oxidation**
$LiClO_4$	**explosive**
$Li_2C_2O_4$	**decomposes to Li_2O, CO, and CO_2**
Li_2CO_3	**decomposes to Li_2O and CO_2**
LiCl	**water soluble, fluxing**
LiF	**water insoluble, fluxing**
$LiNO_3$	**water soluble, may take up some water**
Li_2O	**take up of H_2O and CO_2**
Li_2O_2	**instable**
Li_3PO_4	**water insoluble**
Li_2SO_4	**water soluble, may take up some water**

Beryllium Be

Be: [He]$2s^2$

Atomic number	**4**
Rel. atomic mass	**9.012 g/mol**
Melting point	**1287 °C**
Boiling point	**2469 °C**
Density	**1.85 g/cm^3**

Chemical composition	**Mineral name**
$Be_3Al_2Si_6O_{18}$	**Beryl**

Starting materials	**Properties relevant for solid state chemistry**
Be (metal)	**very toxic, prone to oxidation**
BeO	**take up of H_2O and CO_2**
$Be(OH)_2$	**amphoteric and thus dissolves in diluted acids and bases**
$Be(NO_3)_2$	**water soluble, decomposes to $Be_4O(NO_3)_6$**
BeF_2	**water soluble upon forming $BeF_2(H_2O)_2$**
$BeCl_2$	**hygroscopic**
$BeCO_3$	**decomposes to BeO and CO_2**
$BeSO_4$	**water soluble**
$Be(acac)_3$	**very toxic**

Comment: Beryllium and its compounds are highly toxic!

Boron B

B: [He]$2s^2 2p^1$

Atomic number	**5**
Rel. atomic mass	**10.811 g/mol**
Melting point	**2076 °C**
Boiling point	**3927 °C**
Density	**2.35 g/cm^3**

Chemical composition	**Mineral name**
$Na_2[B_4O_6(OH)_2]\cdot 3\,H_2O$	**Kernit**

Starting materials	**Problem areas in solid state chemistry**
α-B (semimetal)	**low reactivity**
B_2H_6	**reactive, toxic, and colourless gas, condenses at -92.5 °C**
H_3BO_3	**heating yields HBO_2 and then B_2O_3 at 500 °C, flux and melt salt**
B_2O_3	**take up of H_2O and CO_2**
BF_3	**gas, high reactivity**
BCl_3	**hygroscopic**
BBr_3	**hygroscopic**
$BF_3O(C_2H_5)_2$	**reacts violently with H_2O**
$NaBH_4$	**white powder, stable up to 600 °C in dry air, reductive agent**
SmB_6	**melts at 2400 °C, Kondo insulator**

Carbon C

C: [He]$2s^2 2p^2$

Atomic number	**6**
Rel. atomic mass	**12.0107 g/mol**
Melting point	**3550 °C (d)**
Boiling point	**4800 °C (d)**
Density	**3.51 g/cm^3 (d)**

Chemical composition	**Mineral name**
C	**activated carbon**

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Starting materials	**Problem areas in solid state chemistry**
Activated carbon	**reaction with strong oxidants**
Amorphous carbon	**flameable in air**
Charcoal	**flameable in air**
Graphite	**rather inreactive**
Sugar	**decomposes to water and carbon**

Nitrogen N

N: [He]$2s^2 2p^3$

Atomic number	**7**
Rel. atomic mass	**14.007 g/mol**
Melting point	**-210 °C**
Boiling point	**-196 °C**
Density	**1.12 g/dm^3**

Chemical composition	**Mineral name**
Si_3N_4	**Silicon nitride**

Micro crystalline powder of Si_3N_4 (Source: Jan-Niklas Keil, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
N_2 (gas)	**low reactivity up to 1800 °C, inert gas**
LiN_3	**instable, decompses to Li and N_2**
NaN_3	**instable, decompses to Na and N_2**
Mg_3N_2	**yellow, water sensitive, decomposes to form $Mg(OH)_2$ and NH_3**
NH_3	**decomposes to N_2 and H_2**
NH_4Cl	**easily soluble in water, dissociates at 338 °C to NH_3 and HCl**
NH_4NO_2	**explosive $\rightarrow$ N_2 + 2 H_2O**
NH_4NO_3	**explosive $\rightarrow$ N_2O + 2 H_2O**
Si_3N_4	**rather low reactivity**
Si_2N_2O	**very low reactivity „Impact mineral“**

Oxygen O

O: [He]$2s^2 2p^4$

Atomic number	**8**
Rel. atomic mass	**15.999 g/mol**
Melting point	**-218 °C**
Boiling point	**-183 °C**
Density	**1.33 g/dm^3**

Chemical composition	**Mineral name**
ß-PbO_2	**Plattnerite**

Starting materials	**Problem areas in solid state chemistry**
O_2 (gas)	**low reactivity at RT**
O_3	**low stability, strong oxidiser**
Li_2O_2	**reacts with CO_2 to Li_2CO_3 and O_2**
Na_2O_2	**reacts with CO_2 to Na_2CO_3 and O_2**
KO_2	**decomposes in water to KOH and O_2**
SrO_2	**decomposes at 215 °C**
BaO_2	**melts at 450 °C, decomposes at >700 °C**
	soluble in water upon decomposition to $Ba(OH)_2$ and O_2

Fluorine F

O: [He]$2s^2 2p^5$

Atomic number	**9**
Rel. atomic mass	**18.998 g/mol**
Melting point	**-220 °C**
Boiling point	**-188 °C**
Density	**1.58 g/cm^3**

Chemical composition	**Mineral name**
CaF_2	**Fluorite**

Starting materials	**Problem areas in solid state chemistry**
F_2 (gas)	**high reactivity towards furnace materials**
CF_4	**decomposes at high temp. to CF_2 and F_2**
LiF	**somewhat hygroscopic**
MnF_4	**decomposes at high temp. to MnF_2 and F_2**
NaF	**somewhat hygroscopic**
$NaHF_2$	**decomposes at high temp. to NaF and HF**
NH_4F	**decomposes at high temp. to NH_3 and HF**
KF	**hygroscopic**
RbF	**very hygroscopic**
CsF	**very hygroscopic**

Sodium Na

Na: [Ne]3s^1

Atomic number	**11**
Rel. atomic mass	**22.989769 g/mol**
Melting point	**97.72 °C**
Boiling point	**890.0 °C**
Density	**0.968 g/cm^3**

Chemical composition	**Mineral name**
$Na[AlSi_3O_8]$	**Albit**

Starting materials	**Problem areas in solid state chemistry**
Na (metal)	**reacts violently with H_2O, flammable**
NaH	**sensitive to moisture, intolerant with alcohol, acids and oxygen**
NaF	**reactive, little water soluble, flux**
NaCl	**water soluble**
NaBr	**water soluble**
NaI	**air sensitive, incompatible with strong acids**
Na_2CO_3	**soluble in H_2O**
$NaNO_3$	**oxidant, water soluble, may take up some water**
Na_2O	**reacts with H_2O to form NaOH**
Na_2O_2	**reacts with H_2O to form H2O2 and NaOH**
Na_2SiO_3	**incompatible with Tin, Lead and Zinc**

Magnesium Mg

Mg: [Ne]$3s^2$

Atomic number	**12**
Rel. atomic mass	**24.305 g/mol**
Melting point	**650 °C**
Boiling point	**1110 °C**
Density	**1.738 g/cm^3**

Chemical composition	**Mineral name**
$CaMg[CO_3]_2$	**Dolomite**

Starting materials	**Problem areas in solid state chemistry**
Mg (metal)	**reacts violently with H_2O, avoidable conditions are high temperatures and open flames**
MgO	**insoluble in H_2O, air sensitive**
$MgCO_3$	**rather soluble in water, decomposes to MgO at 540 °C**
MgF_2	**low solubility in water ~ 0.076 g/l, useful flux**
$MgCl_2 \cdot 6H_2O$	**hygroscopic**
$MgBr_2$	**instable**
MgI_2	**instable**
$Mg(NO_3)_2 \cdot 6H_2O$	**oxidant, water soluble, may take up some water**
$MgSO_4 \cdot 7H_2O$	**hygroscopic**
Mg_3N_2	**decomposes in water to $Mg(OH)_2$ and NH_3**

Aluminum Al

Al: [Ne]3s^{2}3p^1

Atomic number	**13**
Rel. atomic mass	**26.9815385 g/mol**
Melting point	**660.32 °C**
Boiling point	**2470 °C**
Density	**2.70 g/cm^3**

Chemical composition	**Mineral name**
γ-Al(OH)$_3$, γ/α-AlO(OH)	**Bauxite**

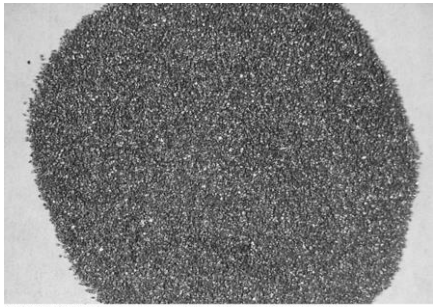
Nanocrystalline powder of Al_2O_3 (Source: Mike Broxtermann, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Al (metal)	**oxidizes to Al_2O_3 → surface passivation**
Al_2O_3	**water insoluble, irreconcilability with strong acids and bases**
$Al(OH)_3$	**with bases convicted to aluminates, unsoluble in neutral water, incompatibility with strong acids**
AlF_3	**soluble in H_2O**
$AlCl_3$	**soluble in H_2O, incompatibility with alcohol and strong oxidizers**
AlN	**caustic, sensitive to hydrolysis**
$Al_2(SO_4)_3$	**irritant, soluble in water**
$Al(NO_3)_3$	**soluble in water**
Al(acetate)$_3$	**decomposes at 200 °C**

Silicon Si

Si: $[Ne]3s^2 3p^2$	
Atomic number	**14**
Rel. atomic mass	**28.085 g/mol**
Melting point	**1414 °C**
Boiling point	**3265 °C**
Density	**2.329 g/cm³**

Chemical composition	**Mineral name**
$(Ba,Ca,Na,K,NH_4)(Al,B,Si)_4O_8$	**Feldspar**



Starting materials	**Problem areas in solid state chemistry**
Si (semimetal)	**low reactivity**
$SiCl_4$	**low boiling point, highly reaction with water, irreconcilability with strong acids and bases**
SiF_4	**gaseous, hydrolysis in water**
Si_3N_4	**low reactivity**
SiO_2	**low reactivity**
$Si(OCH_3)_4$ (TMOS)	**decay in water**
$Si(OC_2H_5)_4$ (TEOS)	**decay in water**
$Si(OC_3H_7)_4$ (TPOS)	**decay in water**

Phosphorus P

P: [Ne]$3s^2 3p^3$

Atomic number	**15**
Rel. atomic mass	**30.974 g/mol**
Melting point	**317.3 °C (white mod.)**
Boiling point	**553.2 °C (white mod.)**
Density	**1.83 g/cm^3 (white mod.)**

Chemical composition	**Mineral name**
$Ca_5(PO_4)_3Cl$	**Apatite**
$LnPO_4$ (Ln = La-Lu)	**Monazite**

Starting materials	**Problem areas in solid state chemistry**
P_4 (red phase)	**toxic and high vapour pressure**
PCl_3	**low boiling point, highly reactive towards water, irreconcilability with strong acids and bases**
P_4O_{10}	**strong exotherm reaction with water → H_3PO_4**
NaH_2PO_4	**decomposes at 170 °C**
Na_2HPO_4	**decomposes at 250 °C**
Na_3PO_4	
$Mg_3(PO_4)_2$	
$Ca_3(PO_4)_2$	
$Ca_5(PO_4)_3(OH)$	
$Ca_2P_2O_7$	

Sulphur S

S: [Ne]3s²3p⁴

Atomic number	**16**
Rel. atomic mass	**32.065 g/mol**
Melting point	**119.6 °C**
Boiling point	**444.6 °C**
Density	**2.07 g/cm³**

Chemical composition	**Mineral name**
$CaSO_4 \cdot H_2O$	**Gypsum**
$SrSO_4$	**Strontianite**
$BaSO_4$	**Baryte**
ZnS	**Zinc blende**
FeS_2	**Pyrite**

Starting materials	**Problem areas in solid state chemistry**
S_8 (solid)	**rather toxic and high vapour pressure**
SCl_2	**highly reactive towards water, forms mustard gas → $S(C_2H_4Cl)_2$**
S_2Cl_2	**used for the vulcanisation of rubber**
SO_2	**gaseous, useful for gas reactions in a tube furnace**
$SOCl_2$	**liquid, decomposes in water to SO_2 and HCl**
$KHSO_4$	**flux**
Na_2SO_4	**flux**
Li_2SO_4	**flux**
K_2SO_4	**flux**
$KAl(SO_4)_2 \cdot 12H_2O$	**highly soluble in water, melts at 92.5 °C**

Chlorine Cl

Cl: $[Ne]3s^2 3p^5$

Atomic number	**17**
Rel. atomic mass	**35.453 g/mol**
Melting point	**-7.0 °C**
Boiling point	**-34.04 °C**
Density	**3.215 g/cm^3 at 273 K**

Chemical composition	**Mineral name**
KCl	**Sylvin**
NaCl	**Rock salt**

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Starting materials	**Problem areas in solid state chemistry**
Cl_2 (gas)	**toxic, very reactive**
NH_4Cl	**sublimes at 340 °C**
LiCl	**melts at 605 °C**
NaCl	**melts at 801 °C**
KCl	**melts at 770 °C**
RbCl	**melts at 715 °C**
CsCl	**melts at 646 °C**
$MgCl_2$	**melts at 714 °C**
$CaCl_2$	**melts at 782 °C**
$SrCl_2$	**melts at 875 °C**
$BaCl_2$	**melts at 963 °C**

Potassium K

K: [Ar]4s^1

Atomic number	**19**
Rel. atomic mass	**39.0983 g/mol**
Melting point	**63.38 °C**
Boiling point	**774 °C**
Density	**1.83 g/cm^3**

Chemical composition	**Mineral name**
KCl	**Sylvine**

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Starting materials	**Problem areas in solid state chemistry**
K (metal)	**reacts violently with H_2O**
KF	**hygroscopic**
KCl	**soluble in H_2O, hygroscopic**
KBr	**soluble in H_2O, hygroscopic**
K_2CO_3	**soluble in H_2O**
K_2SO_4	**soluble in H_2O**
KNO_3	**oxidant**
KOH	**exothermic reaction with H_2O, reacts violently with metals and halogens**
KSCN	**soluble in H_2O**
$KClO_4$	**strong oxidiser, decomposes to KCl and O_2 upon heating**

Calcium Ca

Ca: [Ar]$4s^2$

Atomic number	**20**
Rel. atomic mass	**40.078 g/mol**
Melting point	**842 °C**
Boiling point	**1484 °C**
Density	**1.55 g/cm^3**

Chemical composition	**Mineral name**
$CaCO_3$	**Calcite**

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Starting materials	**Problem areas in solid state chemistry**
Ca (metal)	**intense reaction with water, prone to oxidation**
CaO	**reacts with water to $Ca(OH)_2$, picks up CO_2**
$Ca(OH)_2$	**reacts with CO_2 to form $CaCO_3$**
$CaCO_3$ (calcite)	**insoluble in water, decomposes to CaO at 900 °C**
$CaCl_2 \cdot 6H_2O$	**soluble in water**
CaF_2	**prone to defect formation**
$Ca(NO_3)_2 \cdot 4H_2O$	**oxidant**
$CaSO_4 \cdot 2H_2O$	**hygroscopic, little soluble in water**

Scandium Sc

Sc: [Ar]3d^{1}4s^2

Atomic number	**21**
Rel. atomic mass	**44.955908 g/mol**
Melting point	**1541 °C**
Boiling point	**2730 °C**
Density	**2.985 g/cm^3**

Chemical composition	**Mineral name**
$(Sc,Y)_2Si_2O_7$	**Thortveitite**

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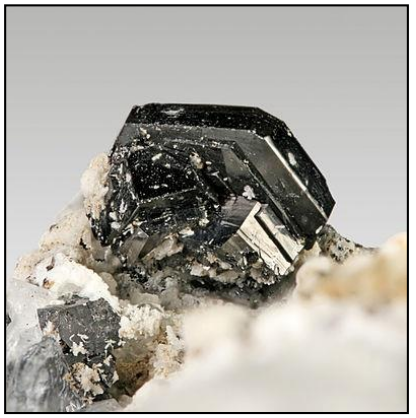
Starting materials	**Problem areas in solid state chemistry**
Sc (metal)	**flammable**
Sc_2O_3	**low reactivity**
ScF_3	**toxic**
$ScCl_3$	**hygroscopic**
$Sc(NO_3)_3 \cdot H_2O$	**oxidant**
$Sc_2(SO_4)_3 \cdot 5H_2O$	**soluble in water**
$Sc_2(C_2O_4)_3 \cdot xH_2O$	**-**

Titanium Ti

Ti: [Ar]$3d^2 4s^2$

Atomic number	**22**
Rel. atomic mass	**47.867 g/mol**
Melting point	**1668 °C**
Boiling point	**3260 °C**
Density	**4.50 g/cm^3**

Chemical composition	**Mineral name**
$FeTiO_3$	**Ilmenit**



Starting materials	**Problem areas in solid state chemistry**
Ti (metal)	**insoluble in water**
TiO_2 (anatase)	**low reactivity**
$TiBr_4$	**reacts violently with water**
$Ti(OCH_2CH_2CH_2CH_3)_4$	**flammable, irritand (Titanium(IV)-butoxide)**
$TiCl_2$	**spontaneously combustable, heavy reaction with water, to handle under inter gas**
$TiCl_3$	**flammable, avoid the contact with air, high reactivity**

Vanadium V

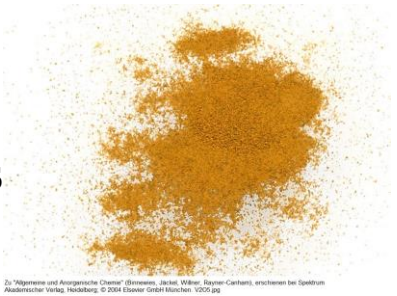
V: [Ar]3d^{3}4s^2

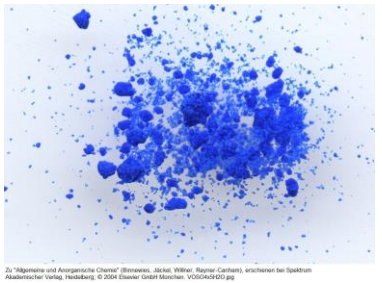
Atomic number	**23**
Rel. atomic mass	**50.9415 g/mol**
Melting point	**1910 °C**
Boiling point	**3407 °C**
Density	**6.11 g/cm^3**

Chemical composition	**Mineral name**
$Pb_5(VO_4)_3Cl$	**Vanadinite**

Source: Didier Descouens

Starting materials	**Problem areas in solid state chemistry**
V (metal)	**oxdises slowly to green vanadium oxide**
V_2O_5	**water soluble, incompatible with strong acids**
KVO_3	**water soluble, decomposes to V_2O_5**
NH_4VO_3	**water soluble, decomposes to V_2O_5**
VCl_3	**hydrolysis in water**
$VOSO_4 \cdot 5H_2O$	**soluble in water, melts at 105 °C**





Chromium Cr

Cr: [Ar]3d^{4}4s^2

Atomic number	**24**
Rel. atomic mass	**51.9961 g/mol**
Melting point	**1907 °C**
Boiling point	**2482 °C**
Density	**7.14 g/cm^3**

Chemical composition	**Mineral name**
$PbCrO_4$	**Crocoite**

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Starting materials	**Problem areas in solid state chemistry**
Cr (metal)	**oxdises slowly to green chromium oxide**
CrO_2 (Chrom(IV)-oxide)	**water soluble, toxic, instable, irritant**
CrO_3 (Chrome(VI)-oxide)	**water soluble, toxic, instable, irritant**
Cr_2O_3 (Chrome(III)-oxide)	**unsoluble in water and diluted acids, melting point 2435 °C**
$Cr_2(SO_4)_3 \cdot H_2O$	**corrosive**
$CrCl_3 \cdot 6H_2O$	**corrosive**
$Cr(NO_3)_3 \cdot 9H_2O$	**oxidising material, not compliable to reducing agents, inaccurate composition**

Manganese Mn

Mn: [Ar]$3d^5 4s^2$

Atomic number	**25**
Rel. atomic mass	**54.938044 g/mol**
Melting point	**1246 °C**
Boiling point	**2100 °C**
Density	**7.43 g/cm^3**

Chemical composition	**Mineral name**
γ-$MnO(OH)_2$	**Manganite**

Micro crystalline powder of MnO_2 (Source: Jan-Niklas Keil, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Mn (metal)	**oxdises slowly to green manganese oxide**
MnO_2	**decomposes chlorides and reducing agents**
MnO	**insoluble in water, dissolves in acids and NH_4Cl**
Mn_2O_3	**irritant**
Mn_3O_4	**insoluble in water, melts at 1705 °C**
$MnCl_2 \cdot 4H_2O$	**soluble in water, not compliable to alkaline materials**
$MnCO_3$	**decomposes in acids**
$Mn(ClO_4) \cdot xH_2O$	**strong oxidiser, explosive**

Iron Fe

Fe: [Ar]$3d^6 4s^2$

Atomic number	**26**
Rel. atomic mass	**55.845 g/mol**
Melting point	**1538 °C**
Boiling point	**2862 °C**
Density	**7.874 g/cm^3**

Chemical composition	**Mineral name**
Fe_3O_4	**Magnetite**

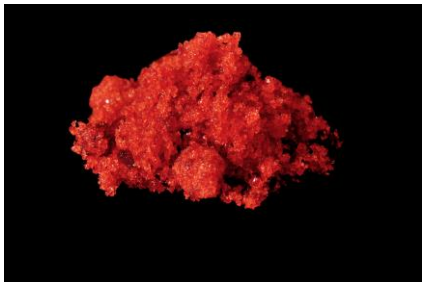
Starting materials	**Problem areas in solid state chemistry**
Fe (metal)	**flammable, insoluble in water**
FeO	**non-stochiometric**
Fe_3O_4	**intolerance with strong acids and peroxides**
Fe_2O_3	**intolerance with strong acids and peroxides**
FeF_3	**intolerance with strong bases, corrosive**
$FeCl_2$	**air-sensitive, intolerance with strong oxidants and sodium/potassium**
$FeCl_3$	**intolerance with alkali metals and strong oxidants**

Cobalt Co

Co: [Ar]$3d^7 4s^2$

Atomic number	**27**
Rel. atomic mass	**58.933194 g/mol**
Melting point	**1495 °C**
Boiling point	**2900 °C**
Density	**8.9 g/cm^3**

Chemical composition	**Mineral name**
CoAsS	**Cobaltite**



Micro crystalline powder of $Co(NO_3)_2 \cdot 6H_2O$
(Source: Danuta Dutczak, RG TOM)

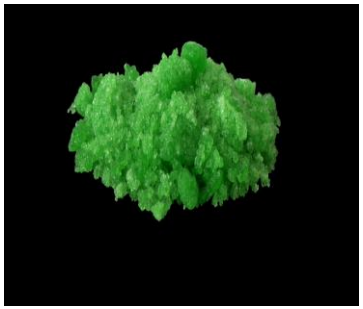
Starting materials	**Problem areas in solid state chemistry**
Co (metal)	**flammable, reacts facilitated with acids (hydrogen created)**
CoO	**low solubility in water, toxic, intolerance with strong oxidants**
Co_3O_4	**low solubility in water, toxic, intolerance with reducting agents**
CoF_3	**corrosive, intolerance to organic materials and reductive agents**
$Co(NO_3)_2 \cdot 6H_2O$	**soluble in water, oxidising**
$Co(CH_3COO)_2$	**soluble in water, toxic**

Nickel Ni

Ni: [Ar]$3d^8 4s^2$

Atomic number	**28**
Rel. atomic mass	**58.6934 g/mol**
Melting point	**1455 °C**
Boiling point	**2730 °C**
Density	**8.908 g/cm^3**

Chemical composition	**Mineral name**
$(Ni,Fe)_9S_8$	**Pentlandite**



Micro crystalline powder of $NiCl_2$ (Source: Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Ni (metal)	**toxic, intolerance with oxygen, hydrogen, acids, fluor, org. solvents and aluminium**
NiO	**toxic, unsoluble in water, intolerance with strong acids**
$Ni(OH)_2$	**toxic, intolerance with strong acids**
$NiCl_2$	**toxic, soluble in water, intolerance with peroxides**
$NiBr_2$	**toxic, intolerance with strong acids and oxidising agents**
$Ni(NO_3)_2 \cdot 6H_2O$	**toxic, intolarance with org. materials, metal powder strong reducting agents**

Copper Cu

Cu: [Ar]$3d^{10}4s^{1}$

Atomic number	**29**
Rel. atomic mass	**63.546 g/mol**
Melting point	**1455 °C**
Boiling point	**2730 °C**
Density	**8.92 g/cm^3**

Chemical composition	**Mineral name**
$CuFeS_2$	**Chalcopyrite**

Starting materials	**Problem areas in solid state chemistry**
Cu (metal)	**soft metal, difficult to mill**
Cu_2O	**toxic, instable in water**
CuO	**toxic, unsoluble in water**
$Cu(OH)_2$	**toxic, intolerance with strong acids**
$CuCl_2$	**toxic, soluble in water**
$Cu(NO_3)_2 \cdot 6H_2O$	**toxic, decomposes to CuO upon heating**
$CuSO_4$	**emetic, decomposes to CuO and SO_3 above 340 °C**
$CuSO_4 \cdot 5H_2O$	**decomposes to $CuSO_4 \cdot 3H_2O$ at 95 °C & to $CuSO_4 \cdot H_2O$ at 116 °C**

Zinc Zn

Zn: [Ar]$3d^{10}4s^2$

Atomic number	**30**
Rel. atomic mass	**65.38 g/mol**
Melting point	**420 °C**
Boiling point	**907 °C**
Density	**7.14 g/cm^3**

Chemical composition	**Mineral name**
ZnS	**Sphalerite**

Starting materials	**Problem areas in solid state chemistry**
Zn (metal)	**prone to oxidation**
ZnO	**dissolves in strong acids and bases**
$Zn(OH)_2$	**dissolves in strong bases**
ZnS	**decomposes in strong acids**
$Zn(NO_3)_2$	**decomposes to ZnO upon heating**
$ZnSO_4$	**decomposes to ZnO, O_2, and SO_3 above 680 °C**
$ZnSO_4 \cdot 7H_2O$	**decomposes to $ZnSO_4 \cdot 6H_2O$ at 39 °C, to $CuSO_4 \cdot H_2O$ at 70 °C, and then to $ZnSO_4$at 240 °C**

Gallium Ga

Ga: [Ar]$3d^{10}4s^24p^1$

Atomic number	**31**
Rel. atomic mass	**69.723 g/mol**
Melting point	**30 °C**
Boiling point	**2204 °C**
Density	**5.91 g/cm^3**

Chemical composition	**Mineral name**
$Ga(OH)_3$	**Soehngeite**

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Starting materials	**Problem areas in solid state chemistry**
Ga (metal)	**prone to oxidation melts at 30 °C**
Ga_2O_3	**dissolves in strong acids and bases**
$Ga(OH)_3$	**decomposes to GaO(OH) at 170 °C**
GaF_3	**insoluble in water, sublimes at 800 °C**
$GaCl_3$	**reacts heavily with water**
$Ga(NO_3)_3$	**decomposes to Ga_2O_3 at 110 °C**
$Ga_2(SO_4)_3$	**decomposes to Ga_2O_3 and SO_3**

Germanium Ge

Ge: [Ar]$3d^{10}4s^24p^2$

Atomic number	**32**
Rel. atomic mass	**72.64 g/mol**
Melting point	**938 °C**
Boiling point	**2820 °C**
Density	**5.32 g/cm^3**

Chemical composition	**Mineral name**
$Cu_{26}Fe_4Ge_4S_3$	**Germanite**

Starting materials	**Problem areas in solid state chemistry**
Ge (metal)	**prone to oxidation**
GeO_2	**dissolves in strong bases**
GeF_4	**gaseous compound**
$GeCl_4$	**colourless liquid, reacts heavily with water**
K_2GeF_6	**soluble in hot water**
$Bi_4Ge_3O_{12}$	**insoluble, very stable oxide, shows strong scintillation**

Arsenic As

As: $[Ar]3d^{10}4s^24p^3$

Atomic number	**33**
Rel. atomic mass	**77.92 g/mol**
Melting point	**615 °C (sublimes)**
Triple point	**817 °C (at 3.63 MPa)**
Density	**5.73 g/cm³**

Chemical composition	**Mineral name**
As_4S_4	**Realgar**

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Starting materials	**Problem areas in solid state chemistry**
As	
As_4	**sublimes at moderate temperature**
As_2O_3	**hydrolysis to arsenious acid**
AsH_3	**highly toxic gas (precursor for MOCVD of semiconductors)**
As_2S_3	**melts at 320 °C**
A_2S_5	**decomposes to As_2S_3 and Sulphur at 100 °C**

Selenium Se

Se: [Ar]$3d^{10}4s^24p^4$

Atomic number	**34**
Rel. atomic mass	**78.97 g/mol**
Melting point	**221 °C**
Boiling point	**685 °C**
Density	**4.19 g/cm^3 (grey Se)**

Chemical composition	**Mineral name**
$CuSe_2$	**Krutaite**

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Starting materials	**Problem areas in solid state chemistry**
Se (grey)	**-**
SeO_2	**dissolves in water to form seleneous acid H_2SeO_3**
SeO_3	**dissolves in water to form selenic acid H_2SeO_4**
K_2SeO_4	**dissolves in water**

Bromine Br

Br: [Ar]$3d^{10}4s^2 4p^5$

Atomic number	35
Rel. atomic mass	79.904 g/mol
Melting point	-7 °C
Boiling point	59 °C
Density	3.14 g/cm^3

Chemical composition	Mineral name
$MgBr_2 \cdot KBr \cdot 6H_2O$	Bromine carnallite

Source: Pavel M. Kartashov

Starting materials	Problem areas in solid state chemistry
Br_2 (liquid)	smelly liquid, high vapor pressure
NaBr	melts at 755 °C
KBr	melts at 732 °C
RbBr	melts at 682 °C, hygroscopic
CsBr	melts at 636 °C, hygroscopic
$KBrO_3$	strong oxidiser, melts at 350 °C, decomposes at 370 °C

Rubidium Rb

Rb: [Kr]5s^1

Atomic number	**37**
Rel. atomic mass	**85.468 g/mol**
Melting point	**39 °C**
Boiling point	**688 °C**
Density	**1.53 g/cm^3**

Chemical composition	**Mineral name**
RbCl	**by-component in Carnallite**

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Starting materials	**Problem areas in solid state chemistry**
Rb (metal)	**reacts violently with H_2O**
RbCl	**soluble in H_2O, hygroscopic**
Rb_2CO_3	**soluble in H_2O**
Rb_2SO_4	**soluble in H_2O**
$RbNO_3$	**oxidant, soluble in H_2O**
RbOH	**exothermic reaction with H_2O, reacts violently with metals and halogens**
$RbClO_4$	**strong oxidiser, decomposes to RbCl and O_2 upon heating**

Strontium Sr

Sr: [Kr]5s^2

Atomic number	**38**
Rel. atomic mass	**87.62 g/mol**
Melting point	**777 °C**
Boiling point	**1412 °C**
Density	**2.63 g/cm^3**

Chemical composition	**Mineral name**
$SrCO_3$	**Strontianite**

Starting materials	**Problem areas in solid state chemistry**
Sr (metal)	**intense reaction with water, prone to oxidation**
$SrCO_3$	**insoluble in water, decomposes to SrO at 1270 °C**
$SrCl_2 \cdot 6H_2O$	**soluble in water**
SrF_2	**prone to defect formation**
$Sr(NO_3)_2 \cdot 4H_2O$	**oxidant, may pick up some water**
SrO	**reacts with water to $Sr(OH)_2$, picks up CO_2, melts at 2430 °C**
$SrSO_4$	**insoluble in water, decomposes to SrO, SO_2 and O_2 at 1300 °C**

Yttrium Y

Y: [Kr]4d^{1}5s^2

Atomic number	**39**
Rel. atomic mass	**88.62 g/mol**
Melting point	**1523 °C**
Boiling point	**3337 °C**
Density	**4.47 g/cm^3**

Chemical composition	**Mineral name**
YPO_4	**Xenotime**

Micro crystalline powder of YPO_4:Bi (Source: FH Münster, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Y (metal)	**reaction with water to $Y(OH)_3$, prone to oxidation**
Y_2O_3	**insoluble in water and diluted acids, refractive index n_D = 1.93**
YF_3	**prone to defect formation**
YCl_3	**water soluble and hydrolysis towards $[Y(H_2O)_8]^{3+}$**
YBr_3	**water soluble and hydrolysis towards $[Y(H_2O)_8]^{3+}$**
$Y(NO_3)_3 \cdot 6H_2O$	**oxidant, may pick up additional water**
$Y(acetate)_3$	**decomposes at 400 °C to Y_2O_3**
$Y_2(C_2O_4)_3 \cdot xH_2O$	**decomposes at 400 °C to Y_2O_3**

Zirconium Zr

Zr: [Kr]4d^{2}5s^2

Atomic number	**40**
Rel. atomic mass	**91.224 g/mol**
Melting point	**1855 °C**
Boiling point	**4377 °C**
Density	**6.52 g/cm^3**

Chemical composition	**Mineral name**
$ZrSiO_4$	**Zircon**

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Starting materials	**Problem areas in solid state chemistry**
Zr (metal)	**dissolves in HCl and H_2SO_4, especially if fluoride is present**
ZrO_2	**insoluble in water and conc. acids, high melting point ~ 2715 °C**
ZrF_4	**hydrolysis in water, prone to defect formation**
$ZrCl_4$	**hydrolysis readily to give $ZrOCl_2$**
$ZrBr_4$	**hydrolysis readily to give $ZrOBr_2$**
$Zr(SO_4)_2 \cdot 4H_2O$	**decomposes to give $Zr(SO_4)_2$ at 380 °C**
$Zr(NO_3)_4 \cdot 5H_2O$	**soluble in water and ethanol**
$ZrSiO_4$	**insoluble, highly refractive and shows birefrigence**
$ZrOCl_2 \cdot 8H_2O$	**soluble in water and ethanol**
$(ZrO)_2(OH)_2CO_3$	**soluble in water and ethanol**

Niobium Nb

Nb: [Kr]4d^{4}5s^1

Atomic number	**41**
Rel. atomic mass	**92.91 g/mol**
Melting point	**2477 °C**
Boiling point	**4744 °C**
Density	**8.57 g/cm^3**

Chemical composition	**Mineral name**
(Fe,Mn)Nb_2O_6	**Columbit**

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Starting materials	**Problem areas in solid state chemistry**
Nb (metal)	**stable due to passiviation but dissolves in HNO_3 and conc. H_2SO_4**
Nb_2O_5	**insoluble in water**
NbF_5	**hydrolysis in water, prone to defect formation**
$NbCl_5$	**hydrolysis readily to give Nb_2O_5, decomposes at 208 °C**
$NbBr_5$	**dissolves in EtOH, hydrolysis readily to give Nb_2O_5**
NbC	**oxidation at temperatures higher than 800 °C**
$Nb(OC_2H_5)_5$	**decomposes to give Nb_2O_5**

Molybdenum Mo

Mo: [Kr]4d^{5}5s^1

Atomic number	**42**
Rel. atomic mass	**95.951 g/mol**
Melting point	**2617 °C**
Boiling point	**4825 °C**
Density	**10.28 g/cm^3**

Chemical composition	**Mineral name**
$CaMoO_4$	**Powellite**

Source: Wikipedia, Rob Lavinsky

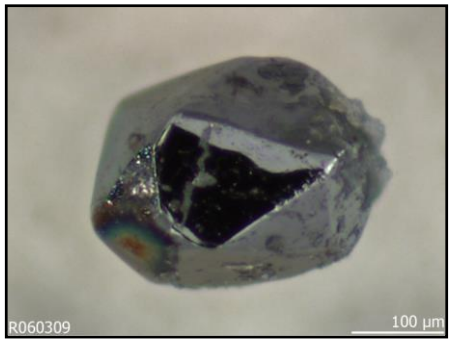
Starting materials	**Problem areas in solid state chemistry**
Mo (metal)	**oxidation begins at 300 °C**
MoO_3	**little soluble in water and starts to sublime at 700 °C**
MoS_2	**stable in inert atmosphere, oxidises in air at 315 °C to MoO_3**
$MoCl_4$	**hydrolysis readily to give MoO_2**
$MoCl_5$	**very hygroscopic solid**
$CaMoO_4$	**little soluble in water**
$(NH_4)_2MoO_4$	**decomposes to polymolybdates upon NH_3 loss**

Ruthenium Ru

Ru: [Kr]4d^{7}5s^1

Atomic number	**44**
Rel. atomic mass	**101.07 g/mol**
Melting point	**2310 °C**
Boiling point	**4150 °C**
Density	**12.37 g/cm^3**

Chemical composition	**Mineral name**
RuS_2	**Laurite**



Source: Mindat.org

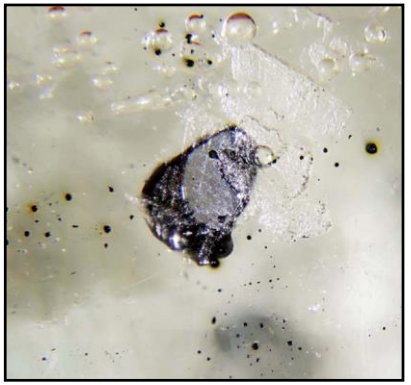
Starting materials	**Problem areas in solid state chemistry**
Ru (metal)	**oxidation begins at 300 °C → RuO_2**
RuO_2	**very little soluble, little reactivity**
RuO_4	**instable gas, strong oxidizer → RuO_2 + O_2**
RuS_2	**stable**
$RuSe_2$	**catalytically active, reduces oxygen**
$RuCl_2$	
$RuCl_3$	**yields acidic solutions due to hydrolysis**
$[Ru(dmso)_4Cl_2]$	**soluble in acetonitrile, acetone, nitromethane**

Rhodium Rh

Rh: [Kr]4d^{8}5s^1

Atomic number	**45**
Rel. atomic mass	**102.9055 g/mol**
Melting point	**1964 °C**
Boiling point	**3727 °C**
Density	**12.38 g/cm^3**

Chemical composition	**Mineral name**
$Rh_{17}S_{25}$	**Miassite**



Source: Wikipedia, David Hospital

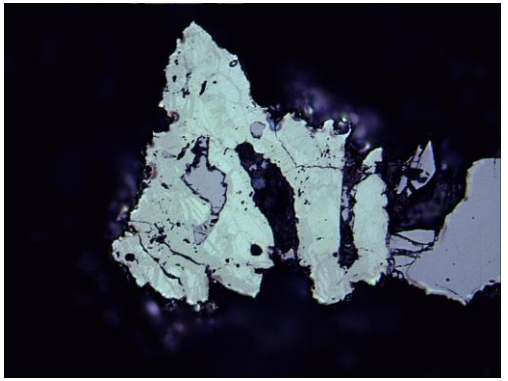
Starting materials	**Problem areas in solid state chemistry**
Rh (metal)	**oxidation begins at 300 °C → RuO_2**
Rh_2O_3	**very little soluble, little reactivity**
RhO_2	**instable gas, strong oxidizer → RuO_2 + O_2**
Rh_2S_3	**stable**
RhF_3	**very reactive solid**
RhF_6	**strongly oxidising, attacks glass**
$RhCl_3$	**decomposes at 800 °C to Rh and Cl_2**
$Rh_2(acetate)_4$	**catalytically active, soluble in polar solvents, also in water**

Palladium Pd

Pd: [Kr]$4d^8 5s^2$

Atomic number	**46**
Rel. atomic mass	**106.42 g/mol**
Melting point	**1555 °C**
Boiling point	**2960 °C**
Density	**11.99 g/cm^3**

Chemical composition	**Mineral name**
$PdSe_2$	**Verbeekite**



Source: Natural History Museum

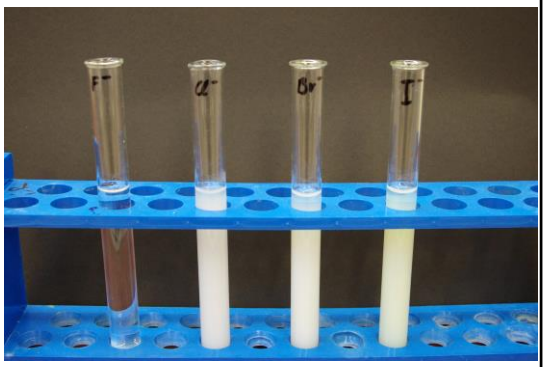
Starting materials	**Problem areas in solid state chemistry**
Pd (metal)	**stable, dissolves in HNO_3 and O_2 containing HCl**
PdO	**black powder, decomposes at 750 °C to yield Pd metal**
PdO_2	**decomposes at 200 °C to yield PdO**
PdS	**brown and insoluble powder**
PdS_2	**contains disulphide bonds**
PdF_2	**insoluble powder**
PdF_4	**strongly oxidising and undergoes rapid hydrolysis in moist air**
$Pd(NO_3)_2$	**oxidative agent**

Silver Ag

Ag: [Kr]4d^{10}5s^{1}

Atomic number	**47**
Rel. atomic mass	**107.87 g/mol**
Melting point	**962 °C**
Boiling point	**2210 °C**
Density	**10.49 g/cm^3**

Chemical composition	**Mineral name**
Ag_2S	**Argentite**



Source: Elke Ungruhe, RG TOM

Starting materials	**Problem areas in solid state chemistry**
Ag (metal)	**stable, can be dissolved in HNO_3 or O_2 containing cyanid solution**
$AgNO_3$	**oxidative agent, easily soluble in water**
AgCl	**white powder, darkens on exposure to light due to Ag formation**
AgBr	**bright yellow powder, darkens on exposure to light**
AgI	**yellow powder, darkens on exposure to light**
Ag_2S	**black powder, very insoluble**
Ag_2O	**dark brown powder, decomposes at 280 °C, not light sensitive**
AgN_3	**instable, explosive**

Cadmium Cd

Cd: [Kr]4d^{10}5s^{2}

Atomic number	**48**
Rel. atomic mass	**112.41 g/mol**
Melting point	**321 °C**
Boiling point	**765 °C**
Density	**8.65 g/cm^3**

Chemical composition	**Mineral name**
CdO	**Monteponite**

Micro crystalline powder of CdSe

Starting materials	**Problem areas in solid state chemistry**
Cd (metal)	**surface oxidises, insoluble in alkaline solution, soluble in HNO_3**
$Cd(NO_3)_2$	**white, hygroscopic powder, decomposes upon heating to CdO**
CdO	**yellow to black powder, insoluble in water, soluble in ammonia**
CdF_2	**highly toxic, cancerogenous, decomposes at 1000 °C**
$CdCl_2$	**hygroscopic, easily soluble in water, absorbs H_2S**
$CdBr_2$	**very hygroscopic, forms a mono and tetrahydrate**
CdI_2	**stable white platelets**
$CdSO_4$	**decomposes at 827 °C**

Indium In

In: [Kr]$4d^{10}5s^{2}5p^{1}$

Atomic number	**49**
Rel. atomic mass	**114.82 g/mol**
Melting point	**157 °C**
Boiling point	**2072 °C**
Density	**7.31 g/cm^3**

Chemical composition	**Mineral name**
In_2O_3	**-**

Micro crystalline powder of In_2O_3 (Source: Jan-Niklas Keil, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
In (metal)	**passivation by the formation of an In_2O_3 layer**
In_2O_3	**yellow insoluble semiconductor**
$In(OH)_3$	**little soluble in water, decomposes at 150 °C**
InF_3	**insoluble in water, melts at 1170 °C**
$InCl_3$	**soluble in water and ethanol, melts at 586 °C**
InN	**decomposes at 300 °C**

Tin Sn

Sn: $[Kr]4d^{10}5s^25p^2$

Atomic number	**50**
Rel. atomic mass	**118.71 g/mol**
Melting point	**232 °C**
Boiling point	**2620 °C**
Density	**7.27 g/cm³ (ß-Sn)**

Chemical composition	**Mineral name**
SnO_2	**Kassiterite**

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Sn pellets

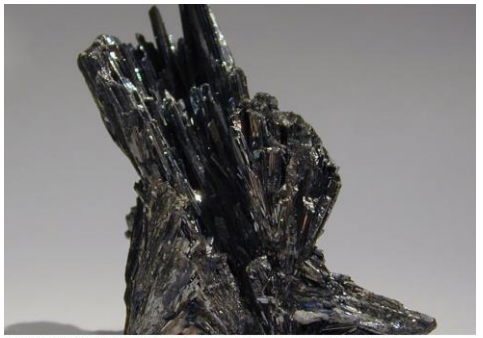
Starting materials	**Problem areas in solid state chemistry**
Sn (metal)	**passivation by the formation of a stable SnO_2 layer**
SnO	**insoluble in water, melts at 1080 °C**
SnO_2	**very insoluble, melts at 1630 °C**
SnF_2	**well soluble in water, melts at 213 °C**
$SnCl_2$	**well soluble in water, melts at 246 °C**
$SnCl_4$	**hydrolysis in water**
$SnSO_4$	**well soluble in water, decomposes at 378 °C**

Antimony Sb

Sb: $[Kr]4d^{10}5s^25p^3$

Atomic number	**51**
Rel. atomic mass	**121.76 g/mol**
Melting point	**631 °C**
Boiling point	**1635 °C**
Density	**6.7 g/cm³**

Chemical composition	**Mineral name**
Sb_2S_3	**Stibnite**



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Starting materials	**Problem areas in solid state chemistry**
Sb (metal)	**stable against air and water**
Sb_2O_3	**insoluble in water, melts at 655 °C**
Sb_2O_5	**insoluble in water, decomposes at 380 °C**
Sb_2S_3	**insoluble in water, melts at 550 °C**
SbF_3	**highly soluble in water, melts at 292 °C**
$SbCl_3$	**well soluble in water, melts at 73 °C**
$SbBr_3$	**decomposes in water, melts at 97 °C**
SbI_3	**decomposes in water, melts at 170 °C**

Tellurium Te

Te: [Kr]4d^{10}5s^{2}5p^{4}

Atomic number	**52**
Rel. atomic mass	**127.60 g/mol**
Melting point	**722.66 °C**
Boiling point	**1261 °C**
Density	**6.24 g/cm^3**

Chemical composition	**Mineral name**
Ag_3AuTe_2	**Petzite**
$AgAuTe_4$	**Sylvanite**

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Starting materials	**Problem areas in solid state chemistry**
Te (metal)	**stable against air and water**
TeO_2	**barely soluble in water, soluble in strong acids and hydroxides**
$Te(OH)_6$	**decomposes to ß-TeO_3**
H_2TeO_3	**metastable**

Iodine I

I: [Kr]4d^{10}5s^{2}5p^{5}

Atomic number	**53**
Rel. atomic mass	**126.90 g/mol**
Melting point	**113.7 °C**
Boiling point	**184.3 °C**
Density	**4.93 g/cm^3**

Chemical composition	Mineral name
$Ca(IO_3)_2$	Lautarite
$7Ca(IO_3)_2 \cdot 8CaCrO_4$	Dietzeite

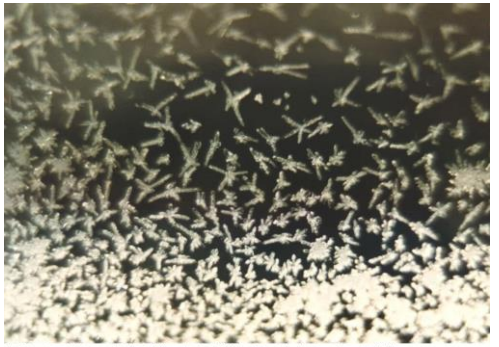
Starting materials	Problem areas in solid state chemistry
I_2 (solid)	highly volatiel, reacts with metals to volatile iodides
LiI	solid state electrolyte, soluble in water, ethanol propanol, ammonia, ethanediol
NaI	hygroscopiy, soluble in water, ethanol and acetone
KI	slowly oxidises in O_2/CO_2 to K_2CO_3, forms with Iodine KI_3
MgI_2	soluble in water, methanol, ether, ammonia

Xenon Xe

Xe: [Xe]

Atomic number	**54**
Rel. atomic mass	**131.29 g/mol**
Melting point	**-111.7 °C**
Boiling point	**-108 °C**
Density	**5.898 kg/m^3 at 273.15 K**

Chemical composition	**Mineral name**
XeF_2	**-**



White crystals of XeF_2

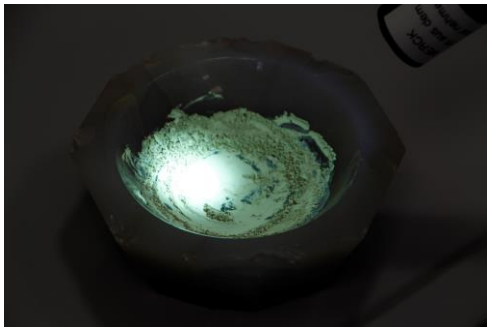
Starting materials	**Problem areas in solid state chemistry**
Xe (gas)	**inert, reacts in discharges with halides or oxygene**
XeF_2	**hydrolysis in H_2O, etchant for Si**
XeF_4	**hydrolsis in H_2O to XeO_3 and Xe**
XeF_6	**hydrolsis in H_2O to XeO_3**
XeO_2	**very instable, present in Martian quartz crystals**
XeO_3	**strong oxidant, prone to violent explosion**
XeO_4	**strong oxidant, very prone to explosion**

Caesium Cs

Cs: [Xe]6s^1

Atomic number	**55**
Rel. atomic mass	**132.91 g/mol**
Melting point	**28.5 °C**
Boiling point	**671 °C**
Density	**1.93 g/cm^3**

Chemical composition	**Mineral name**
Cs	



Micro crystalline powder of $CsVO_3$ upon 395 nm excitation (Source: Dr. David Enseling, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Cs (metal)	**reacts explosive with H_2O**
CsF	**well soluble in H_2O**
CsCl	**soluble in H_2O, hygroscopic**
Cs_2CO_3	**soluble in H_2O**
Cs_2SO_4	**soluble in H_2O**
$CsNO_3$	**oxidant, soluble in H_2O**
CsOH	**exothermic reaction with H_2O, reacts violently with metals and halogens**
$CsClO_4$	**strong oxidiser, decomposes to CsCl and O_2 upon heating**

Barium Ba

Ba: [Xe]6s^2

Atomic number	**56**
Rel. atomic mass	**137.33 g/mol**
Melting point	**727 °C**
Boiling point	**1897 °C**
Density	**3.62 g/cm^3**

Chemical composition	Mineral name
$BaCO_3$	Witherite
$BaSO_4$	Baryte

Micro crystalline powder of $BaSO_4$
(Dr. Danuta Dutczak, RG TOM)

Starting materials	Problem areas in solid state chemistry
Ba (metal)	reacts lively with H_2O
BaF_2	somewhat soluble in H_2O
$BaCl_2$	soluble in H_2O, hygroscopic
$BaCO_3$	insoluble in H_2O, soluble in acids
$BaSO_4$	insoluble in H_2O (white standard)
$Ba(NO_3)_2$	oxidant, well soluble in H_2O
$Ba(OH)_2$	exothermic reaction with H_2O, yields strongly alkaline solution
BaO_2	strong oxidiser, decomposes to BaO and O_2 upon heating

Lanthanum La

La: [Xe]6s^{2}5d^1

Atomic number	**57**
Rel. atomic mass	**138.91 g/mol**
Melting point	**920 °C**
Boiling point	**3470 °C**
Density	**6.17 g/cm^3**

Chemical composition	**Mineral name**
(Ce,La,Th,Nd,Y)PO_4	**Monazite**
(Ce,La,Y)CO_3F	**Bastnäsite**

Micro crystalline powder of La_2O_3 (Dr. Danuta Dutczak, RG TOM)

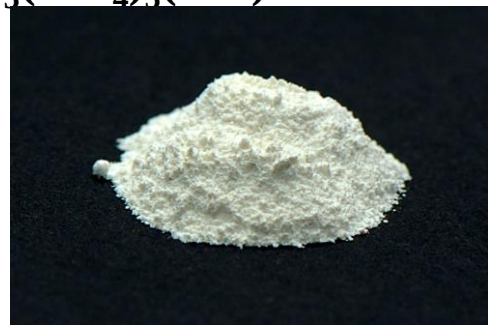
Starting materials	**Problem areas in solid state chemistry**
La (metal)	**reacts lively with H_2O**
LaF_3	**insoluble in H_2O, HCl or HNO_3**
$LaCl_3$	**well soluble in H_2O, hygroscopic**
$LaBr_3$	**well soluble in H_2O, hygroscopic**
La_2O_3	**reacts with water to form $La(OH)_3$**
$La_2(CO_3)_3$	**insoluble in H_2O, reacts with phosphate to $LaPO_4$**
$La(NO_3)_3 \cdot 6H_2O$	**mild oxidant, well soluble in H_2O, forms tetrahydrate at 126 °C**
$La(OH)_3$	**exothermic reaction with H_2O, yields strongly alkaline solution**
LaB_6	**insoluble in water, low work function, thus use as electron emitter**

Cerium Ce

Ce: [Xe]6s^{2}5d^{1}4f^1

Atomic number	**58**
Rel. atomic mass	**140.12 g/mol**
Melting point	**795 °C**
Boiling point	**3470 °C**
Density	**6.77 g/cm^3**

Chemical composition	Mineral name
$(Ce,La,Th,Nd,Y)PO_4$	Monazite
$(Ce,La,Y)CO_3F$	Bastnäsite
$(Ca,Ce,La,Y)_2(Al,Fe)_3(SiO_4)_3(OH)$	Allanite



Micro crystalline powder of CeO_2
(Dr. Danuta Dutczak, RG TOM)

Starting materials	Problem areas in solid state chemistry
Ce (metal)	reacts with H_2O and ethanol
CeF_3	insoluble in H_2O, soluble in strong acids
$CeCl_3$	well soluble in H_2O, hygroscopic, forms $CeCl_3 \cdot 7H_2O$
$CeBr_3$	well soluble in H_2O, ethanol and acetone, hygroscopic
Ce_2O_3	insoluble in water, soluble in acids upon formation of $Ce(OH)_3$
CeO_2	reacts with CO to form Ce_2O_3
$Ce(NO_3)_3 \cdot 6H_2O$	mild oxidant, well soluble in H_2O, forms tetrahydrate at 126 °C
$Ce(OH)_3$	exothermic reaction with H_2O, yields strongly alkaline solution
$Ce(SO_4)_2$	slightly soluble in water, yellow powder, strong oxidiser

Praseodymium Pr

Pr: [Xe]$6s^2 4f^3$

Atomic number	**59**
Rel. atomic mass	**140.91 g/mol**
Melting point	**935 °C**
Boiling point	**3130 °C**
Density	**6.475 g/cm^3**

Chemical composition	**Mineral name**
$(Ce,La,Ca)_9(Fe,Mg)[(OH)_3\|SiO_3(OH)\|(SiO_4)_6]$	**Cerite**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**
$(Ce,La,Y)CO_3F$	**Bastnäsite**

Micro crystalline powder of Pr_6O_{11} (Dr. Jan-Niklas Keil, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Pr (metal)	**reacts with H_2O to form $Pr(OH)_3$**
PrF_3	**insoluble in H_2O, soluble in strong acids**
$PrCl_3$	**well soluble in H_2O, hygroscopic, forms $PrCl_3 \cdot 7H_2O$**
$PrBr_3$	**well soluble in H_2O, ethanol and acetone, hygroscopic**
Pr_2O_3	**insoluble in water, hygroscopic, reacts to $Pr(OH)_3$**
Pr_6O_{11}	**insoluble in water, soluble in acids upon formation of $Pr(OH)_3$**
$Pr(NO_3)_3 \cdot H_2O$	**80 g/l in in water**
$Pr_2(SO_4)_3 \cdot 8H_2O$	**170 g/l in water**

Neodymium Nd

Nd: $[Xe]6s^2 4f^4$

Atomic number	60
Rel. atomic mass	144.24 g/mol
Melting point	1024 °C
Boiling point	3074 °C
Density	7.01 g/cm^3

Chemical composition	Mineral name
$(Ce,La,Th,Nd,Y)PO_4$	Monazite
$(Ce,La,Y)CO_3F$	Bastnäsite

Micro crystalline powder of Nd_2O_3
(Dr. Jan-Niklas Keil, RG TOM)

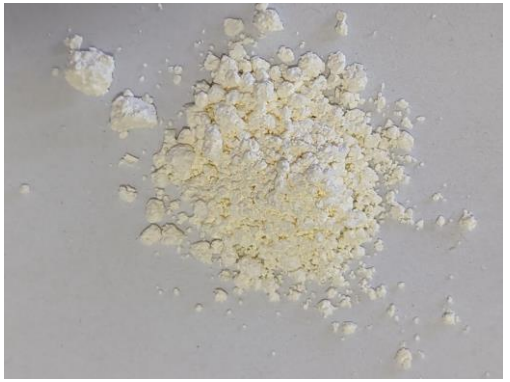
Starting materials	Problem areas in solid state chemistry
Nd (metal)	reacts slowly with cold H_2O to form $Pr(OH)_3$
NdF_3	insoluble in H_2O, used for the manufacture of fluoride glasses
$NdCl_3$	well soluble in H_2O & ethanol, forms in H_2O upon heating NdOCl
$NdBr_3$	well soluble in H_2O, hygroscopic to form $NdBr_3 \cdot 6H_2O$
Nd_2O_3	3 mg/l in water
$Nd_2(CO_3)_3 \cdot 8H_2O$	insoluble in water, dissolves in diluted acids
$Nd(CH_3COO)_3 \cdot 4H_2O$	7.77 g/l in in water, decomposes at 320-430 °C to $Nd_2O_2(CO_3)$
$Nd_2(SO_4)_3 \cdot 8H_2O$	8 g/l in water, decomposes at 40 °C to $Nd_2(SO_4)_3 \cdot 5H_2O$

Samarium Sm

Sm: $[Xe]6s^2 4f^6$

Atomic number	**62**
Rel. atomic mass	**150.36 g/mol**
Melting point	**1072 °C**
Boiling point	**1900 °C**
Density	**7.52 g/cm^3**

Chemical composition	**Mineral name**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**
$(Ce,La,Y)CO_3F$	**Bastnäsite**



Micro crystalline powder of Sm_2O_3 (Dr. Jan-Niklas Keil, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Sm (metal)	**reacts slowly with cold, quickly with hot H_2O to form $Sm(OH)_3$**
SmF_3	**insoluble in H_2O**
$SmCl_3$	**well soluble in H_2O & ethanol, hygroscopic**
$SmBr_3$	**well soluble in H_2O, hygroscopic, decomposes in water**
Sm_2O_3	**insoluble in water**
$Sm(OH)_3$	**insoluble in water, decomposes to SmO(OH) upon heating**
SmB_6	**insoluble in water, moderator in fission reactors**
$Sm(NO_3)_3 \cdot 6H_2O$	**well soluble in water, decomposes to $SmO(NO_3)$ at 460 °C**

Europium Eu

Eu: $[Xe]6s^2 4f^7$

Atomic number	**63**
Rel. atomic mass	**151.96 g/mol**
Melting point	**826 °C**
Boiling point	**1440 °C**
Density	**5.245 g/cm³**

Chemical composition	**Mineral name**
YPO_4	**Xenotime**
$(Ce,La,Y)CO_3F$	**Bastnäsite**

Micro crystalline powder of Eu_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Eu (metal)	**reacts with H_2O to form H_2 and $Eu(OH)_3$, oxidises in air to Eu_2O_3**
EuF_3	**insoluble in H_2O**
$EuCl_3$	**well soluble in H_2O, hygroscopic**
$EuBr_3$	**well soluble in H_2O, hygroscopic**
Eu_2O_3	**insoluble in water, can be reduced to Eu_3O_4 and then EuO**
$Eu(OH)_3$	**insoluble in water, decomposes to Eu_2O_3 upon heating**
$Eu_2(SO_4)_3$	**well soluble in water**
$Eu(NO_3)_3 \cdot 6H_2O$	**well soluble in water**

Gadolinium Gd

Gd: [Xe]$6s^2 5d^1 4f^7$

Atomic number	**64**
Rel. atomic mass	**157.25 g/mol**
Melting point	**1312 °C**
Boiling point	**3000 °C**
Density	**7.886 g/cm^3**

Chemical composition	**Mineral name**
YPO_4	**Xenotime**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**

Micro crystalline powder of Gd_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Gd (metal)	**reacts with H_2O to form H_2 and $Gd(OH)_3$, oxidises in air to Gd_2O_3**
GdF_3	**insoluble in H_2O**
$GdCl_3$	**well soluble in H_2O, hygroscopic**
$GdBr_3$	**well soluble in H_2O, hygroscopic**
GdI_3	**well soluble in H_2O, hygroscopic**
Gd_2O_3	**insoluble in water, decomposes to Gd_2O_3 upon heating**
$Gd(OH)_3$	**insoluble in water**
$Gd(NO_3)_3 \cdot 6H_2O$	**well soluble in water**

Terbium Tb

Tb: [Xe]6s^{2}4f^9

Atomic number	**65**
Rel. atomic mass	**158.93 g/mol**
Melting point	**1356 °C**
Boiling point	**3123 °C**
Density	**8.253 g/cm^3**

Chemical composition	**Mineral name**
(Y,Ca,Er,La,Ce,U,Th)(Nb,Ta,Ti)$_2$O$_6$	**Euxenite**
(Ce,La,Th,Nd,Y)PO$_4$	**Monazite**

Micro crystalline powder of Tb_4O_7 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Tb (metal)	**reacts with H_2O to form H_2 and $Tb(OH)_3$**
TbF_3	**insoluble in H_2O**
$TbCl_3$	**well soluble in H_2O, hygroscopic**
$TbBr_3$	**well soluble in H_2O, hygroscopic**
TbI_3	**well soluble in H_2O, hygroscopic**
Tb_4O_7	**insoluble in water, reacts with atomic Oxygen to dark red TbO_2**
$Tb_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Tb(NO_3)_3 \cdot 6H_2O$	**well soluble in water**

Dysprosium Dy

Dy: [Xe]$6s^2 4f^{10}$

Atomic number	**66**
Rel. atomic mass	**162.50 g/mol**
Melting point	**1407 °C**
Boiling point	**2600 °C**
Density	**8.559 g/cm^3**

Chemical composition	**Mineral name**
$(Ce,La,Y)CO_3F$	**Bastnäsite**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**

Micro crystalline powder of $_2O_3$ (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Dy(metal)	**reacts with H_2O to form H_2 and $Dy(OH)_3$**
DyF_3	**insoluble in H_2O**
$DyCl_3$	**well soluble in H_2O, hygroscopic**
$DyBr_3$	**well soluble in H_2O, hygroscopic**
DyI_3	**well soluble in H_2O, hygroscopic**
Dy_2O_3	**insoluble in water**
$Dy_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Dy(NO_3)_3 \cdot 6H_2O$	**well soluble in water**

Holmium Ho

Ho: $[Xe]6s^2 4f^{11}$

Atomic number	**67**
Rel. atomic mass	**164.93 g/mol**
Melting point	**1461 °C**
Boiling point	**2600 °C**
Density	**8.78 g/cm^3**

Chemical composition	**Mineral name**
$(Y,Ln)_2FeBe_2O_2(SiO_4)_2$	**Gadolinite**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**

Micro crystalline powder of Ho_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Ho(metal)	**reacts with H_2O to form H_2 and $Ho(OH)_3$**
HoF_3	**insoluble in H_2O**
$HoCl_3$	**well soluble in H_2O, hygroscopic**
$HoBr_3$	**well soluble in H_2O, hygroscopic**
HoI_3	**well soluble in H_2O, hygroscopic**
Ho_2O_3	**insoluble in water**
$Ho_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Ho(NO_3)_3 \cdot 6H_2O$	**well soluble in water**
$Ho(ClO_4)_3$	**strong oxidiser**

Erbium Er

Er: $[Xe]6s^2 4f^{12}$

Atomic number	**68**
Rel. atomic mass	**167.26 g/mol**
Melting point	**1529 °C**
Boiling point	**2900 °C**
Density	**9.07 g/cm^3**

Chemical composition	**Mineral name**
$(Y,Ln)_2FeBe_2O_2(SiO_4)_2$	**Gadolinite**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**

Micro crystalline powder of Er_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Er(metal)	**reacts with H_2O to form H_2 and $Er(OH)_3$**
ErF_3	**insoluble in H_2O**
$ErCl_3$	**well soluble in H_2O, hygroscopic**
$ErBr_3$	**well soluble in H_2O, hygroscopic**
ErI_3	**well soluble in H_2O, hygroscopic**
Er_2O_3	**insoluble in water**
$Er_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Er(NO_3)_3 \cdot 5H_2O$	**well soluble in water**
$Er_2(C_2O_4)_3$	**decomposes to form Er_2O_3**

Thulium Tm

Tm: [Xe]6s^{2}4f^{13}

Atomic number	**69**
Rel. atomic mass	**168.93 g/mol**
Melting point	**1545 °C**
Boiling point	**1950 °C**
Density	**9.32 g/cm^3**

Chemical composition	**Mineral name**
YPO_4	**Xenotime**
$(Ce,La,Th,Nd,Y)PO_4$	**Monazite**

Micro crystalline powder of Tm_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Tm(metal)	**reacts with H_2O to form H_2 and $Tm(OH)_3$**
TmF_3	**insoluble in H_2O**
$TmCl_3$	**well soluble in H_2O, hygroscopic**
$TmBr_3$	**well soluble in H_2O, hygroscopic**
TmI_3	**well soluble in H_2O, hygroscopic**
Tm_2O_3	**insoluble in water**
$Tm_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Tm(NO_3)_3 \cdot 5H_2O$	**well soluble in water**
$Tm_2(C_2O_4)_3 \cdot 6H_2O$	**decomposes to form Tm_2O_3**

Ytterbium Yb

Yb: $[Xe]6s^2 4f^{14}$

Atomic number	**70**
Rel. atomic mass	**173.05 g/mol**
Melting point	**824 °C**
Boiling point	**1430 °C**
Density	**6.97 g/cm^3**

Chemical composition	**Mineral name**
$(Y,Ln)_2FeBe_2O_2(SiO_4)_2$	**Gadolinite**
YPO_4	**Xenotime**

Micro crystalline powder of Yb_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Yb(metal)	**reacts with H_2O to form H_2 and $Yb(OH)_3$**
YbF_3	**insoluble in H_2O**
$YbCl_3$	**well soluble in H_2O, hygroscopic**
$YbBr_3$	**well soluble in H_2O, hygroscopic**
YbI_3	**well soluble in H_2O, hygroscopic**
Yb_2O_3	**insoluble in water**
$Yb_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Yb(NO_3)_3 \cdot 5H_2O$	**well soluble in water**
$Yb_2(C_2O_4)_3 \cdot 6H_2O$	**decomposes to form Yb_2O_3**

Lutetium Lu

Lu: [Xe]6s^{2}5d^{1}4f^{14}

Atomic number	**71**
Rel. atomic mass	**177.97 g/mol**
Melting point	**1652 °C**
Boiling point	**3330 °C**
Density	**9.84 g/cm^3**

Chemical composition	**Mineral name**
$(Y,Ln)_2FeBe_2O_2(SiO_4)_2$	**Gadolinite**
YPO_4	**Xenotime**

Micro crystalline powder of Lu_2O_3 (Dr. Danuta Dutczak, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
Lu(metal)	**reacts with H_2O to form H_2 and $Lu(OH)_3$**
LuF_3	**insoluble in H_2O**
$LuCl_3$	**well soluble in H_2O, hygroscopic**
$LuBr_3$	**well soluble in H_2O, hygroscopic**
LuI_3	**well soluble in H_2O, hygroscopic**
Lu_2O_3	**insoluble in water**
$Lu_2(SO_4)_3 \cdot 8H_2O$	**well soluble in water**
$Lu(NO_3)_3 \cdot 5H_2O$	**well soluble in water**
$Lu(acac)_3$	**reacts with bpy/phen to form $[Lu(acac)_3(bpy)]$ / $[Lu(acac)_3(phen)]$**

Hafnium Hf

Hf: [Xe]$6s^2 5d^2 4f^{14}$

Atomic number	**72**
Rel. atomic mass	**178.49 g/mol**
Melting point	**2233 °C**
Boiling point	**4603 °C**
Density	**13.28 g/cm^3**

Chemical composition	**Mineral name**
$HfSiO_4$	**Hafnon**
$ZrSiO_4$	**Zirkon**

Micro crystalline powder of HfO_2 (Julia Exeler, RG TOM)

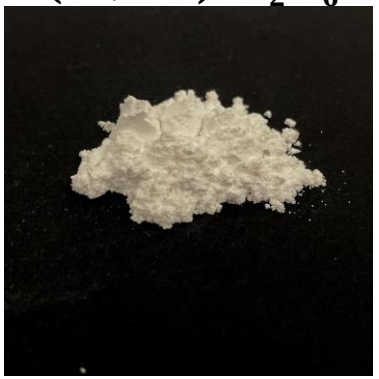
Starting materials	**Problem areas in solid state chemistry**
Hf(metal)	**reacts upon heating to form HfO_2**
HfO_2	**insoluble in H_2O**
HfC	**insoluble in H_2O, very hard, oxidation sets in at about 500 °C**
HfN	**insoluble in H_2O, very hard**
HfB_2	**insoluble in H_2O, oxidation stable up to 1500 °C**
HfF_4	**insoluble in water**
$HfCl_4$	**volatile**
HfI_4	**volatile**
Ta_4HfC_5	**compound with highest melting point ~ 3990 °C**

Tantalum Ta

Ta: [Xe]6s^{2}5d^{3}4f^{14}

Atomic number	**73**
Rel. atomic mass	**180.95 g/mol**
Melting point	**3017 °C**
Boiling point	**5420 °C**
Density	**16.65 g/cm^3**

Chemical composition	**Mineral name**
Columbit	**(Fe,Mn)Nb$_2$O$_6$**
Tantalit	**(Fe,Mn)Ta$_2$O$_6$**



Micro crystalline powder of Ta$_2$O$_5$ (Julia Exeler, RG TOM)

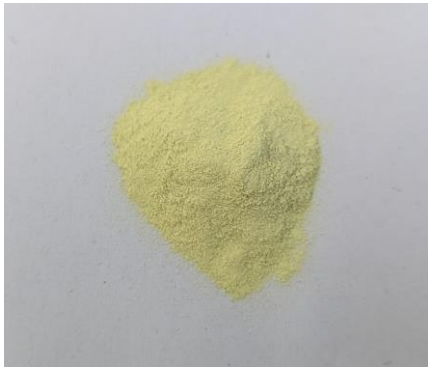
Starting materials	**Problem areas in solid state chemistry**
Ta(metal)	**reacts upon heating to form Ta$_2$O$_5$**
Ta$_2$O$_5$	**insoluble in H$_2$O and acids**
LaTaO$_4$	**insoluble in H$_2$O and acids**
TaC	**insoluble in H$_2$O, very hard, soluble in conc. HF or H$_2$SO$_4$**
TaN	**insoluble in H$_2$O, very hard, thin film insulator**
TaF$_5$	**insoluble in water**
TaCl$_5$	**volatile, hydrolysis to form TaOCl$_3$**
K$_2$TaF$_7$	**little soluble in water**

Tungsten W

W: [Xe]$6s^2 5d^4 4f^{14}$

Atomic number	**74**
Rel. atomic mass	**183,84 g/mol**
Melting point	**3422 °C**
Boiling point	**5930 °C**
Density	**19.25 g/cm^3**

Chemical composition	**Mineral name**
Scheelite	**$CaWO_4$**
Wolframite	**$(Mn,Fe)WO_4$**



Micro crystalline powder of WO_3 (Dr. Jan-Niklas Keil, RG TOM)

Starting materials	**Problem areas in solid state chemistry**
W(metal)	**reacts upon heating to form WO_3**
WO_3	**insoluble in H_2O**
Na_2WO_4	**insoluble in H_2O**
$CaWO_4$	**insoluble in H_2O**
$PbWO_4$	**insoluble in H_2O**
ZrW_2O_8	**insoluble in H_2O, very hard, negative thermal expansion**
WF_6	**reacts with water to form HF and H_2WO_4**
WS_2	**insoluble in H_2O**
WC	**insoluble in H_2O, extremly hard**