Inorganic Chemistry Supplement

Context

Inorganic chemistry plays a key role in the science of materials, catalysis, biological processes, nanotechnology, and other multi-disciplinary fields.

Conceptual Topics

Topics that are part of the inorganic curriculum are listed below. It is recognized that many curricula will not cover all of these topics, and that some topics may be distributed among several different courses.

- Atomic Structure. Spectra and orbitals, ionization energy, electron affinity, shielding and effective nuclear charge.
- Covalent Molecular Substances. Geometries (symmetry point groups), valence bond theory (hybridization, σ, π, δbonds), molecular orbital theory (homo and heteronuclear diatomics, multi-centered MO, electron-deficient molecules, π -donor and acceptor ligands), acid-base.
- Main Group Elements. Synthesis, structure, physical properties, variations in bonding motifs, acid-base character, and reactivities of the elements and their compounds.
- Transition Elements and Coordination Chemistry. Ligands, coordination number, stereochemistry, bonding motifs, nomenclature; ligand field and molecular orbital theories, Jahn-Teller effects, magnetic properties, electronic spectroscopy (term symbols and spectrochemical series), thermodynamic aspects (formation constants, hydration enthalpies, chelate effect), kinetic aspects (ligand substitution, electron transfer, fluxional behavior), lanthanides and actinides.
- Organometallic Chemistry. Metal carbonyls, hydrocarbon and carbocyclic ligands, 18-electron rule (saturation and unsaturation), synthesis and properties, patterns of reactivity (substitution, oxidative addition and reductive elimination, insertion and de-insertion, nucleophilic attack on ligands, isomerization, transmetallation, stereochemical nonrigidity).
- Solid State Materials. Close packing in metals and metal compounds, metallic bonding, band theory, magnetic properties, conductivity, semiconductors, insulators, and defects.
- Special Topics. Catalysis and important industrial processes, bioinorganic chemistry, condensed materials containing chain, ring, sheet, cage, and network structures, supramolecular structures, nanoscale structures and effects, surface chemistry, environmental and atmospheric chemistry.

Practical Topics

The goal of the inorganic laboratory is to give students experience with a range of techniques used in the synthesis and characterization of inorganic compounds and to give them experience in preparing and analyzing various classes of inorganic compounds (coordination, organometallic, and main group compounds, extended solids) and bonding/structural motifs (fluxional behavior, metal-metal multiple bonds, ligands with multiple bonding modes, 3-center bonds, hapticity). Among the techniques that are recommended for inclusion in the inorganic laboratory are the following:

- **Synthetic Methods** that make use of inert atmospheres (dry box/bag, Schlenk methods), a high temperature furnace/heated tube, a vacuum line, a high pressure autoclave, and electrochemical apparatus.

- **Purification Methods** such as column/ion exchange chromatography, sublimation, recrystallization and resolution of optically active compounds.

- **Characterization Methods** that involve measurements of magnetic susceptibility, conductivity, oxidation-reduction potentials, X-ray diffraction, IR, UV-vis, NMR (variable temperature, multinuclear, multidimensional), optical rotation, ESR, Mössbauer, and mass spectrometry, electronic properties (band-gaps, conductivity, etc.)..

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In the ideal case, experiments should be more than a list of instructions to be followed. Instead, they should illustrate how characterization methods provide insight into fundamental electronic structure and structure-property relationships (by studying families of related compounds for instance). Instructors are encouraged to consult the chemical education literature for ideas about suitable experiments. The list below provides examples of complexes that have been described in the chemical education literature, as a starting point for development of laboratory projects.

- **Coordination Compounds** – $[Co(NH_3)_5Cl]Cl_2$, $Mn(acac)_3$, $[Co(en)_3]Cl_3$, $CrCl_2(H_2O)_4^+$, $Cr(acac)_3$, $[Cr(NH_3)_6](NO_3)_3]$, $Cu(O_2CMe)_2{\bullet}H_2O$, $[Co(en)_2Cl_2]Cl$, [Co(o-phen)$_3$]Br$_2$, Co(salen), $Mo_2(O_2CMe)_4$, $K_4Mo_2Cl_8$.

- **Organotransition Metal Compounds** – (η^6-1,3,5-$Me_3C_6H_3$)$Mo(CO)_3$, $Cp_2Fe_2(CO)_4$, $Ir(Cl)(CO)(PPh_3)_2$, Cp_2Ni, $PtCl_2$(1,5-cyclooctadiene), [Pd(Cl)((η^3-allyl)]$_2$, Cp_2Fe, $Rh(Cl)(CO)(PPh_3)_2$, $Fe_3(CO)_{12}$.

- **Main Group Element Compounds** – $BH_3{:}NH_2$(t-Bu), $B(OR)_3$, C_{60}, GeH_4, $Sn(Cl)_2(R)_2$, $Ph_2PCH_2CH_2PPh_2$, $K_2S_2O_8$, $PhBCl_2$, $K(C_2B_9H_{11})$, ICl_3, [I(pyridine)$_2$](NO_3), $[PCl_4][SbCl_6]$, $Me_3N{:}BF_3$, siloxane polymers.

- **Solid State Compounds** – $YBa_2Cu_3O_7$, $VO(PO_4)(H_2O)_2$, a zeolite, semiconductors, $CrCl_3$.

- **Bioinorganic Compounds** – Ni(glycinate)$_n^{(2-n)+}$, copper(II) tetraphenylporphyrin, Pd(nucleoside)$_2$(Cl)$_2$, Cu(saccharin)$_2$(H$_2$O)$_4$, Cu(glycinate)$_2$, cis-platin, cobaloxime model complexes.

- **Special Topics** – quantum dots, nanocrystals, templated synthesis of nanowires, self-assembled monolayers, catalysis, ferrofluids, and metalloorganic frameworks (MOFs).

Illustrative Modes of Coverage

The conceptual topics are usually taught in one or two courses dedicated to inorganic chemistry (one foundation and one in-depth), with the in-depth course having a physical chemistry pre-requisite in the ideal case. It is possible for course material to be spread over several courses that do not focus explicitly on inorganic chemistry, as long as a reasonable breadth and exposure to principles of inorganic chemistry are included. Examples might include courses on the synthesis of organic and inorganic compounds, polymeric and supramolecular synthesis and structures, materials chemistry and nanotechnology, catalysis, bioinorganic, organometallic, atmospheric and environmental chemistry. The inorganic laboratory experience can be offered as a course dedicated to inorganic chemistry or as part of a laboratory course that integrates inorganic practical experiences with those of the other areas of chemistry.

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