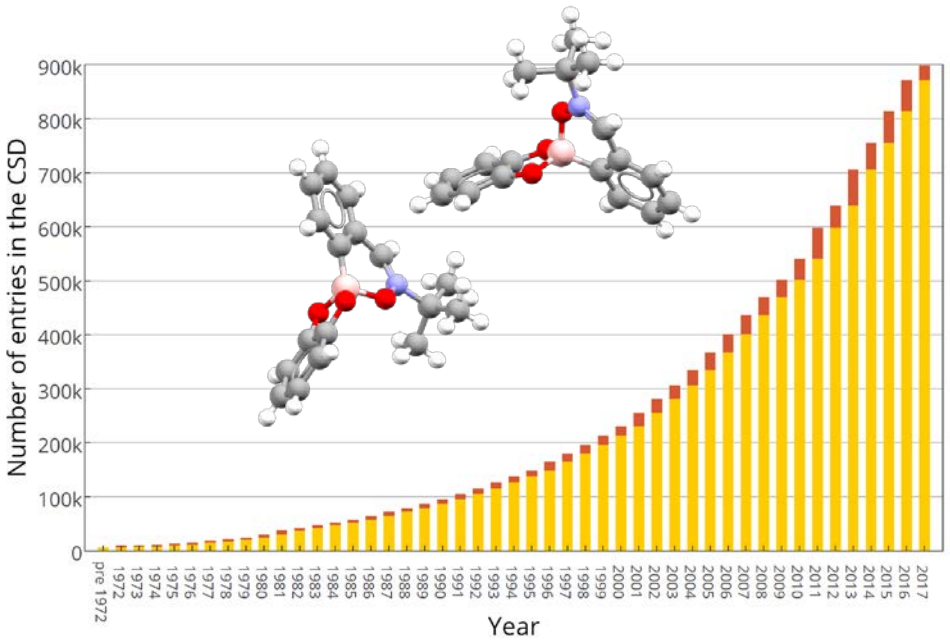
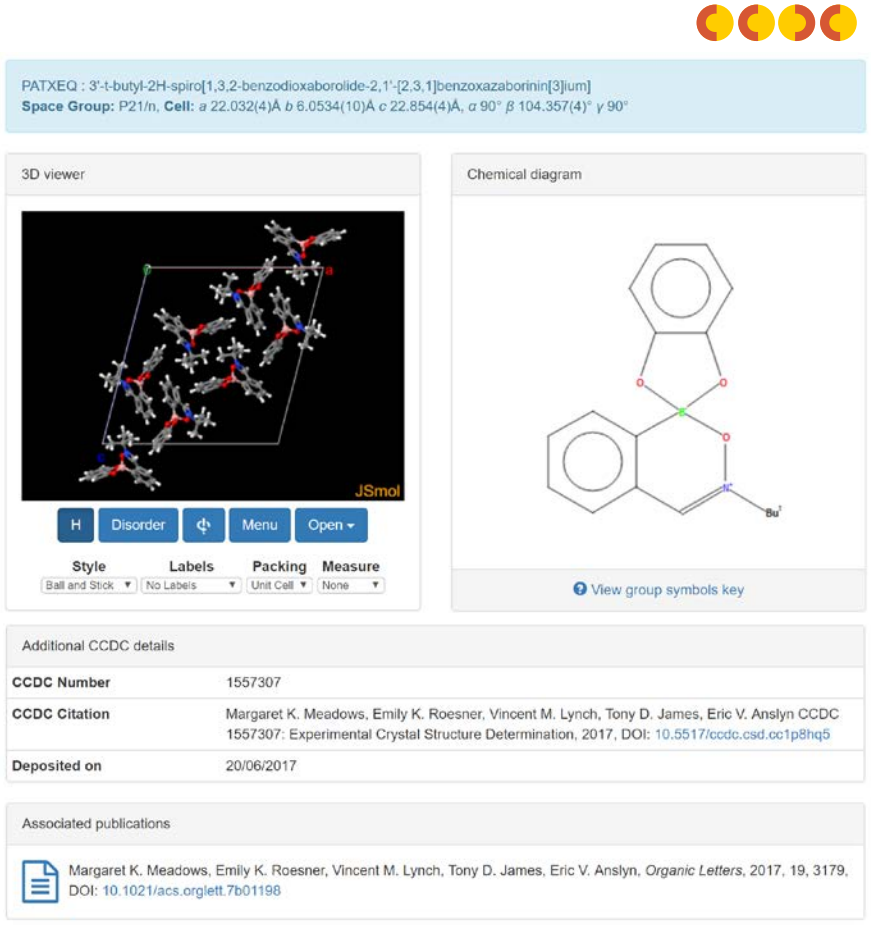
Organometallics & InChI

August 2017

The Cambridge Structural Database



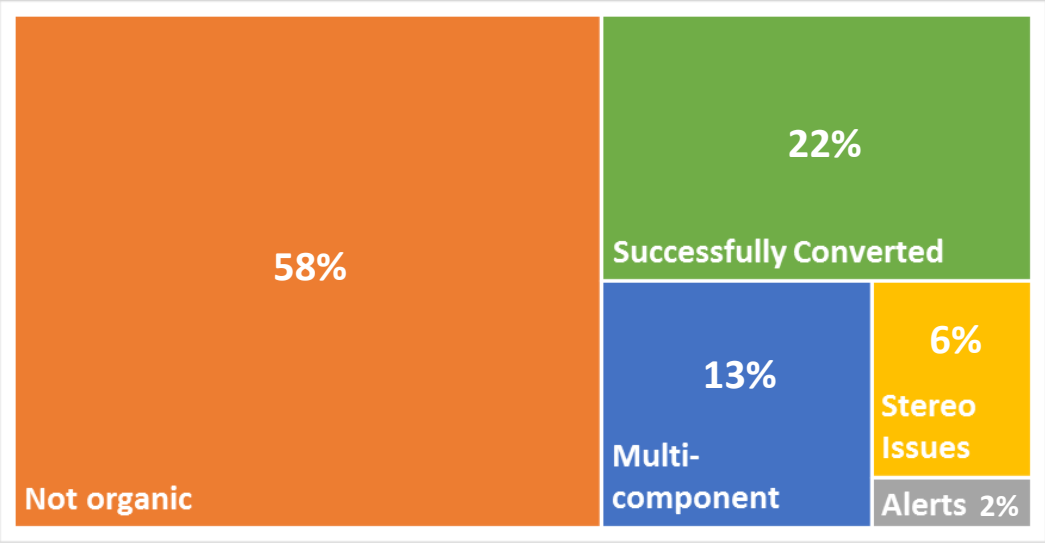


- **900,000+ small-molecule crystal structures**
- Over 60,000 datasets deposited annually
- Enriched and annotated by experts
- Structures available for anyone to download
- Links to over 1,000 journals

https://dx.doi.org/10.5517/ccdc.csd.cc1p8hq5

The CSD & InChIs

- **GOAL:** Reliable standard InChI representations to enable intersection of the CSD with e.g. ChemSpider and PubChem
- Based on a subset of 495,751 entries from CSD V5.36, InChIs successfully generated for 108,570 entries - **that's just 22%**

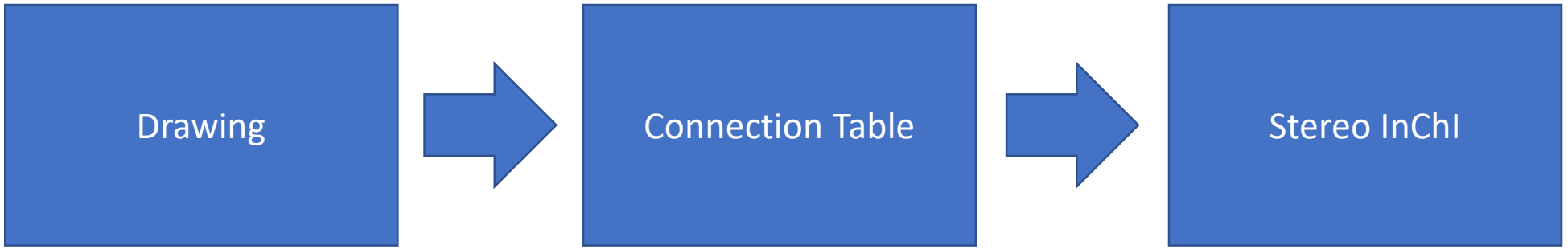


Order of filtering:

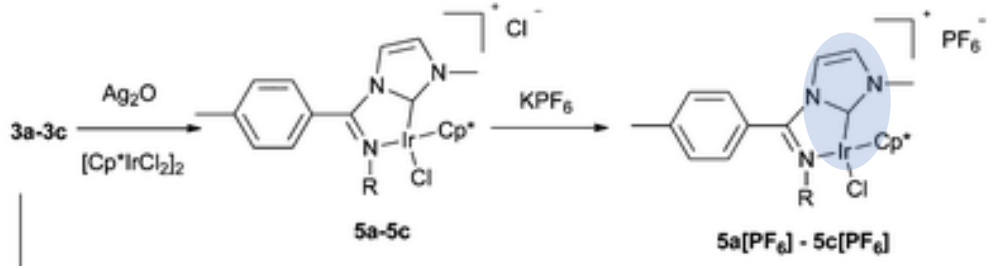
- *Not organic*
- *Multi-component*
- *InChi alerts*
- *Stereochemistry Issues*

Previously, at the EBI

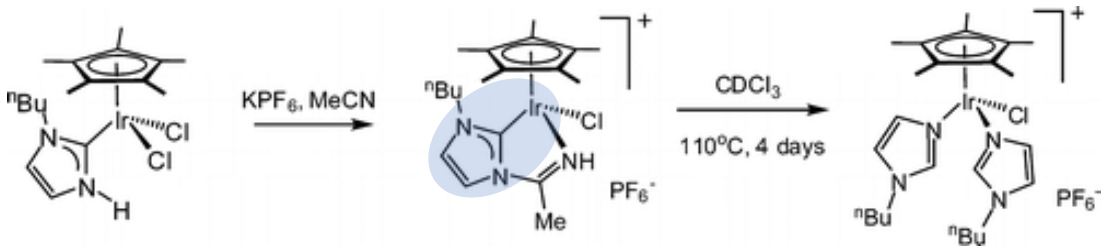
- Organometallic and coordination compounds: What can we achieve by August?
  - **Colin:** Determine tasks for stereo package for developer
  - **John:** Identify supported V2000 extensions, idioms and bugs
  - **Andrey:** Review examples of advanced normalization and suggest drawing rules



Different Expressions

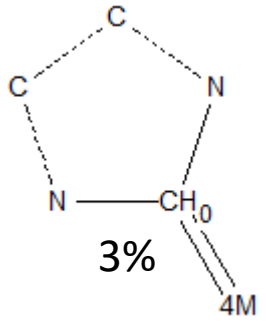


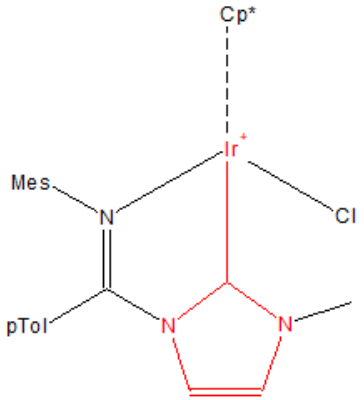
http://pubs.rsc.org/en/content/articlehtml/2012/dt/c2dt31989f



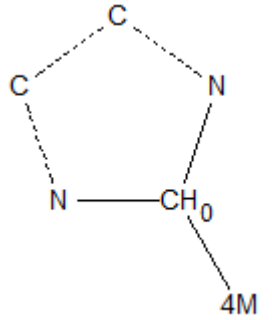
http://pubs.acs.org/doi/abs/10.1021/om700498w

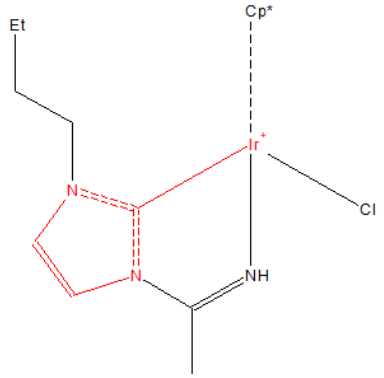
N = 9468 (CSD 5.38)



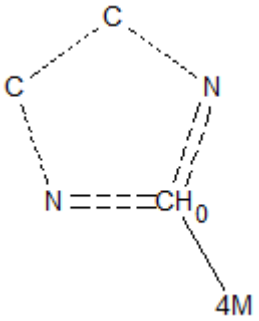


ECIWUK





LIMXAH



Reliable Representation

- How best to reliably represent organometallics?
  - dative vs covalent bonds?
  - explicit hydrogens/valencies?
  - dummy atoms?
  - zero-order bonds?

MOL V3000

```
1 = single
2 = double
3 = triple
9 = coordination
10 = hydrogen
```

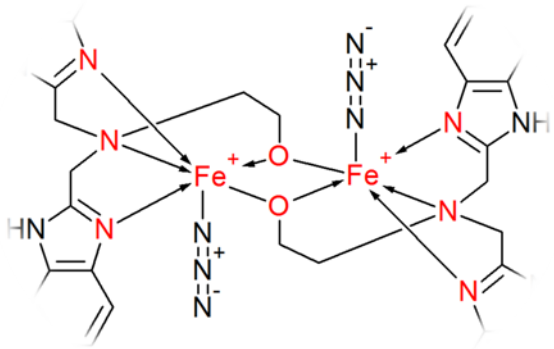
* excluding query bond types

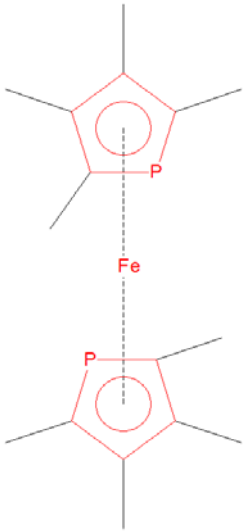
ACD/Labs MOL V2000 Extensions

```
M  ZZF  3   1  41   2  42   3  43
M  ZZH   1  5   2   3   4   5   6
M  ZZH   2  5   7   8   9  10  11
M  ZZH   3  5  12  14  15  16  17
M  ZZE  2  42  18  43  18
```

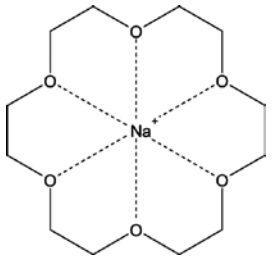
PubChem SDF
PUBCHEM_NONSTANDARDBOND

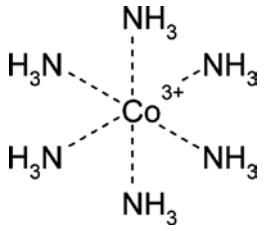
```
1 Single Bond
2 Double Bond
3 Triple Bond
4 Quadruple Bond
5 Dative Bond
6 Complex Bond
7 Ionic Bond
```

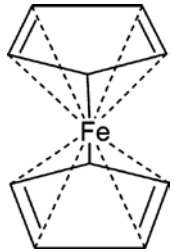




Accurate Specification of Molecular Structures: The Case for Zero-Order Bonds and Explicit Hydrogen Counting. **Alex M. Clark.**
J. Chem. Inf. Model., 2011, 51 (12), 3149. doi:10.1021/ci200488k





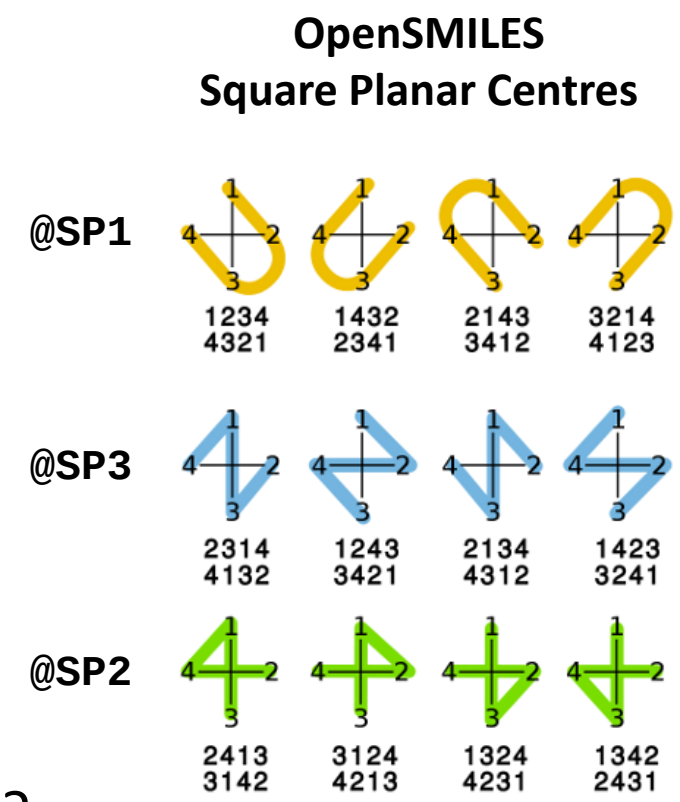


CSD Bond Types

- ❑ Single
- ❑ Double
- ❑ Triple
- ❑ Quadruple
- ❑ Aromatic
- ❑ Delocalised
- ❑ Pi
- ❑ Polymeric

Stereochemistry

- Task 1: Identify geometries from 3D and 2.5D
  - octahedral
  - square planar
  - trigonal bipyramidal
  - square pyramidal
- Task 2: Generate priority ordering
  - using CIP?
  - or any stable ordering?
  - relevance of IR-9.3.5.3 Red Book Priming Convention?



Putative Principles

- Chemically-distinct systems should produce distinct InChIs
- A reliable representation for input into the InChI generator is possible without the need for a “delocalised” bond type
- Assume we don’t want to reconstruct original structure from the InChI (except *via* AuxInfo layer)
- Can we retain disconnection and avoid ambiguity?

Session Goals

- Update on progress since EBI
  - normalization/disconnection (Andrey)
  - representation (John)
  - stereochemistry (Ian channelling Colin)
- Identification of next steps
  - do we have enough information to start coding?
  - do we have sufficient test cases?
- Motivational use-cases
  - what positive transformation could organometallic InChI enable?

Putative Principles

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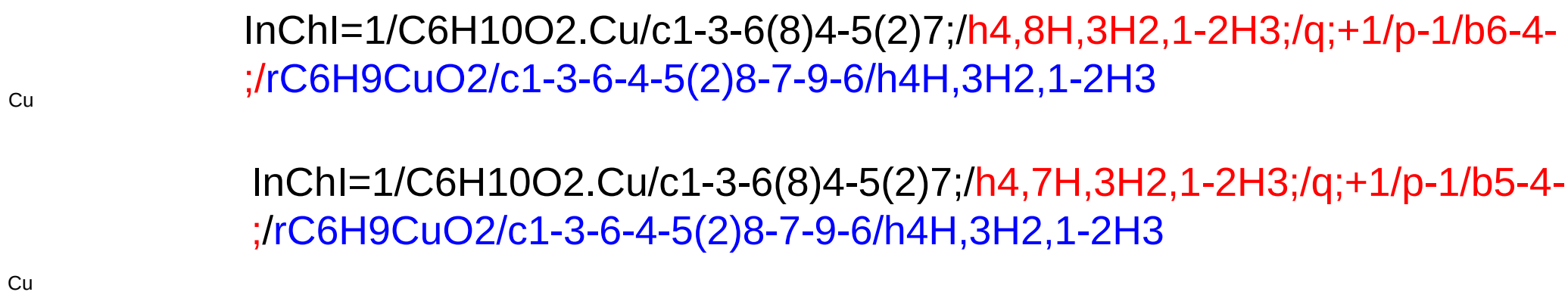
Putative Principles

- Chemically-distinct systems should produce distinct InChIs
- A reliable representation for input into the InChI generator is possible without the need for a “delocalised” bond type
- **Don’t** assume we don’t want to reconstruct original structure from the InChI (except *via* AuxInfo layer)
- **Can’t assume** we can retain disconnection and avoid ambiguity

Discussion Summary

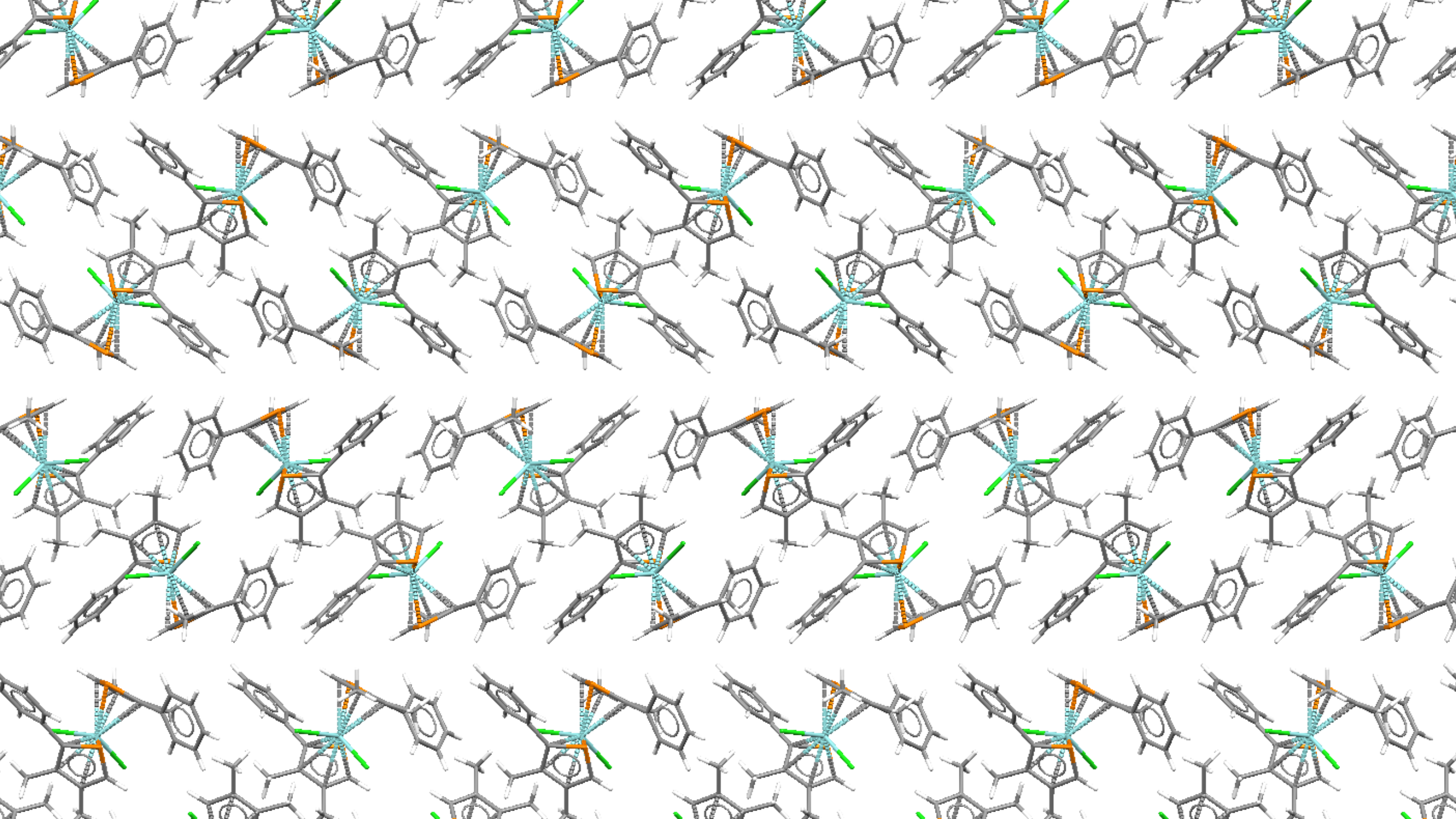
- What approach do nomenclature rules take?
  - disconnect, name ligands, represent reconnection
- Disconnection
  - current disconnection rules likely to give rise to ambiguity
  - do we need to disconnect?
  - **look more closely at (non-standard) InChI reconnection layer**



Discussion Summary

- Stereochemistry
  - CIP priorities – we don't need to go there
  - could instead use OpenSMILES approach but perhaps just as hard to implement
  - given a priority order, could use Red Book rules to generate configuration indices
  - **focus on getting the connectivity component sorted first**

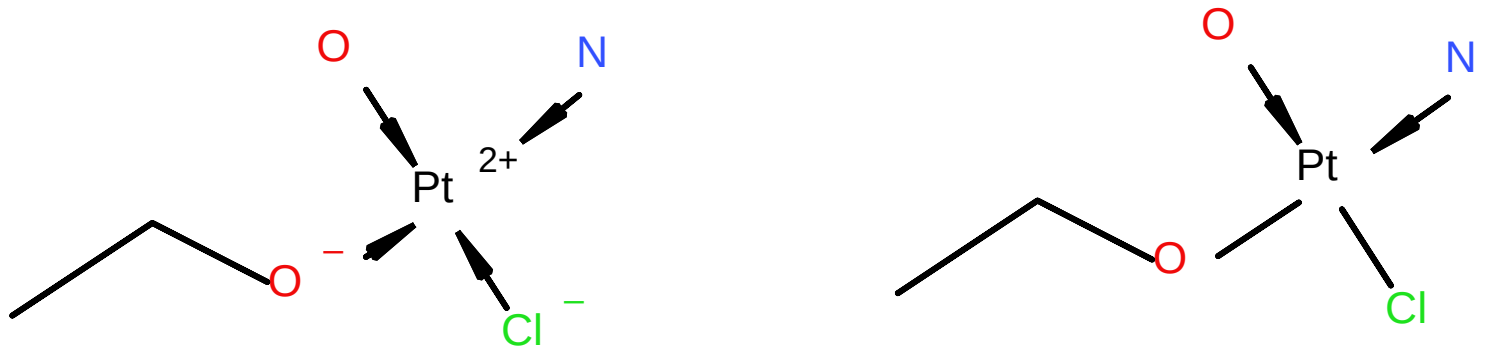
- External challenges
  - chemists are not consistent in how they draw metal-organic structures
  - tools may not internally represent metal-organic structures the same way
  - identical structures may end up represented different ways in MOL files
  - **for now, find input representations that might enable InChI algorithm development**



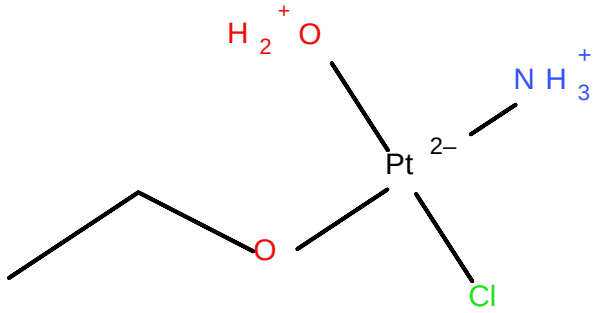
Bond Types and Disconnection

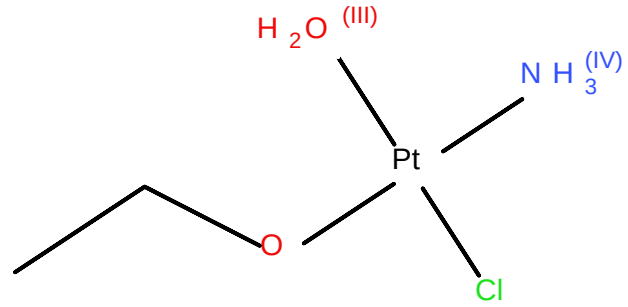
V3000 Coordination Bonds

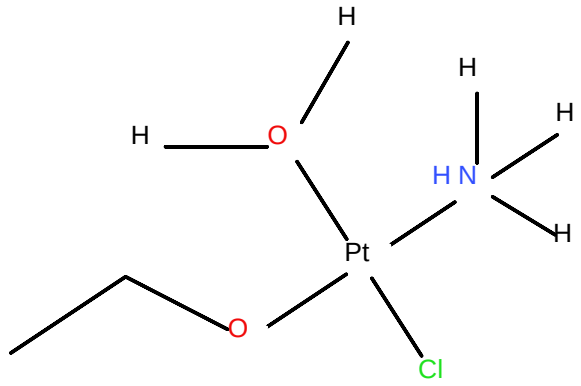
- Currently coordination bonds are not supported:
  - message: type="error (no InChI)" value="Unrecognized bond type: 9"
- pi-Bonding was already discussed
  - proposed to use bonds to every atoms to represent hapta-coordination

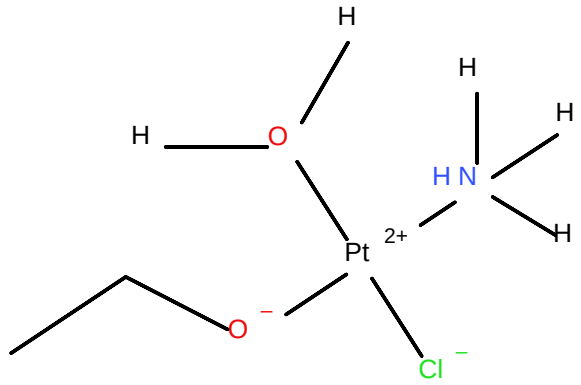


Normalisation – treat as single bonds



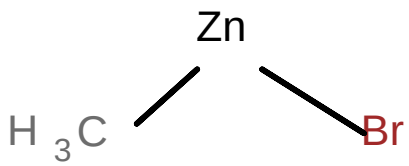






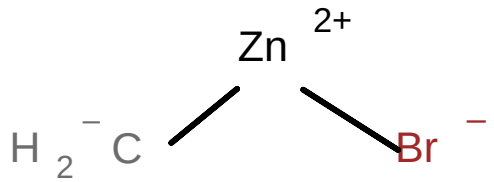
(Spurious H a display artefact)

KOAWFNMWAQBXOA-UHFFFAOYSA-M



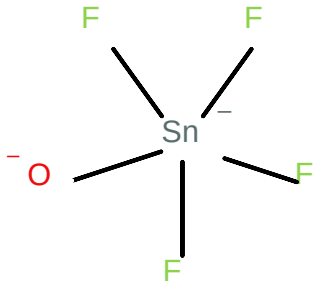
InChI=1S/CH3.BrH.Zn/h1H3;1H;/q;;+1/p-1

SOHOYYHPFIUFDH-UHFFFAOYSA-M



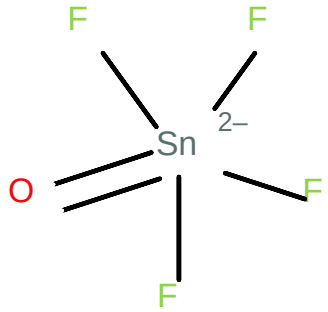
InChI=1S/CH2.BrH.Zn/h1H2;1H;/q-1;;+2/p-1

DOJWUFOAVZTCJR-UHFFFAOYSA-M



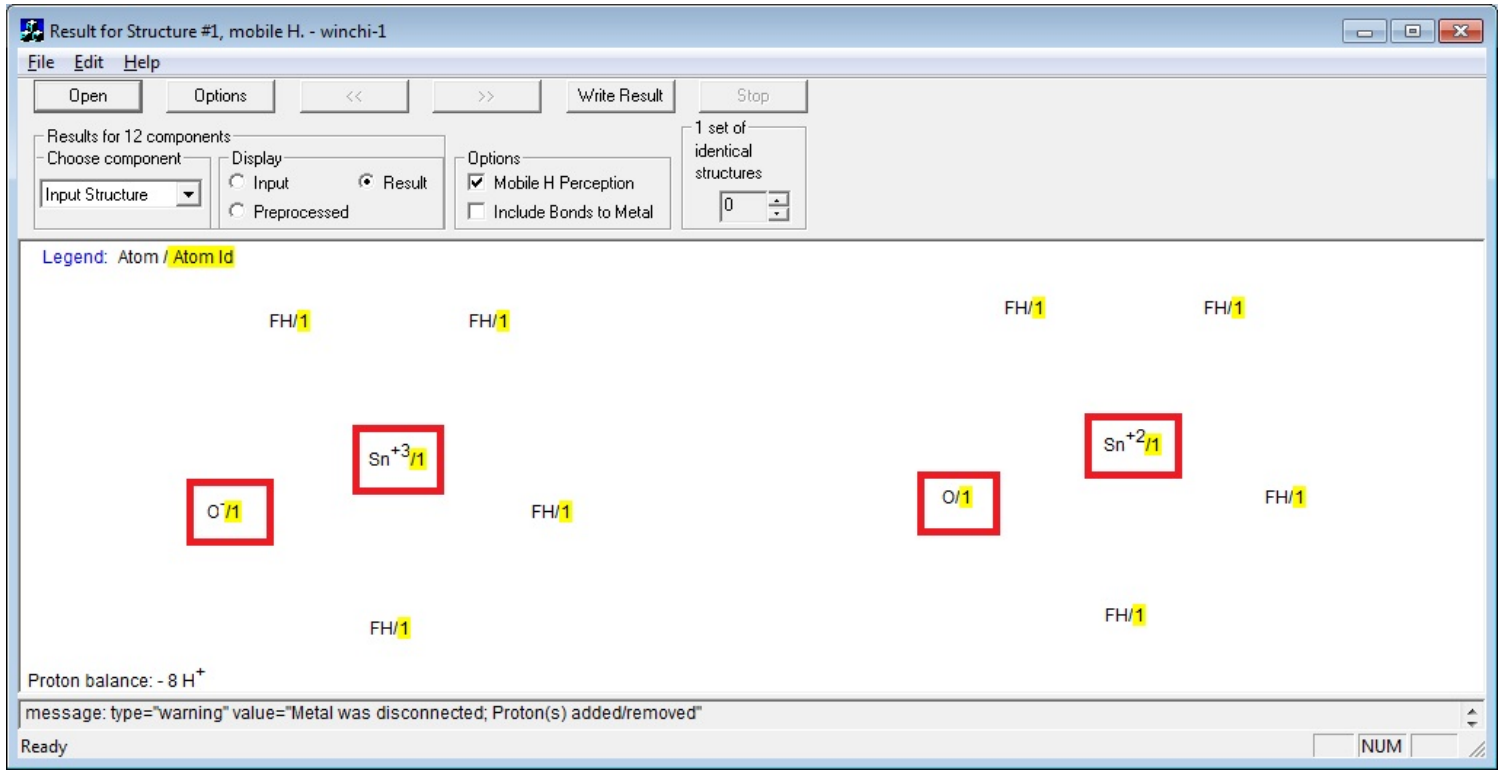
InChI=1S/4FH.O.Sn/h4*1H;;/q;;;;-1;+3/p-4

KKYRWVTZCFOANR-UHFFFAOYSA-J



InChI=1S/4FH.O.Sn/h4*1H;;/q;;;;;+2/p-4

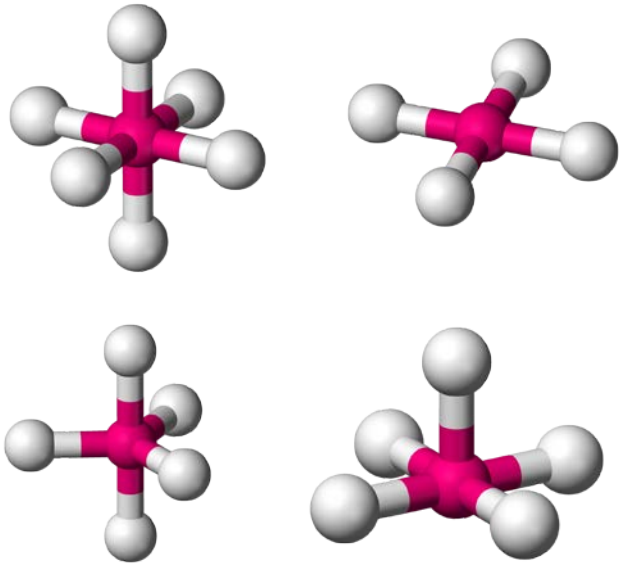
ATUYBIGISSSQTG-UHFFFAOYSA-J


Result for Structure #1, mobile H. - winchi-1
File Edit Help
Open
Options
<<
>>
Write Result
Stop
Results for 12 components
Choose component
Input Structure
Display
Input
Result
Preprocessed
Options
Mobile H Perception
Include Bonds to Metal
1 set of identical structures
0
Legend: Atom / Atom Id
FH/1
FH/1
FH/1
FH/1
Sn+3/1
O-/1
FH/1
FH/1
Sn+2/1
O/1
FH/1
FH/1
Proton balance: - 8 H+
message: type="warning" value="Metal was disconnected; Proton(s) added/removed"
Ready
NUM

Si

Stereochemistry

TASK 1: Identify Geometries



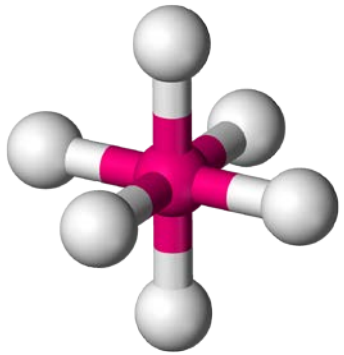
- Identify the following geometries around atom centres:
  - octahedral
  - square planar
  - trigonal bipyramidal
  - square pyramidal
- Cover three-dimensional structures first
  - there are test structures provided by CCDC and Elsevier
  - we should be careful about what we distribute with any code developed
- When we cover two-dimensional structures, only cover those drawn with wedged and dashed bonds
  - do not try to infer stereochemistry from flat bonds.

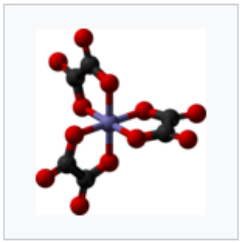
cis-$[CoCl_2(NH_3)_4]^+$

trans-$[CoCl_2(NH_3)_4]^+$

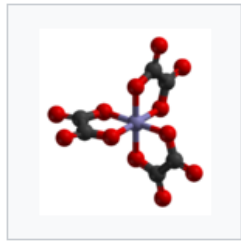
fac-$[CoCl_3(NH_3)_3]$

mer-$[CoCl_3(NH_3)_3]$

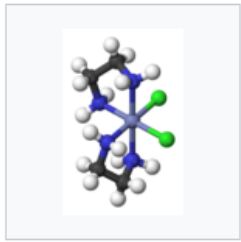




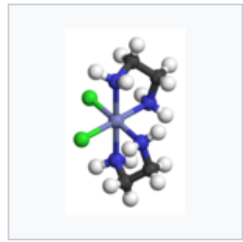
Λ-$[Fe(ox)_3]^{3-}$



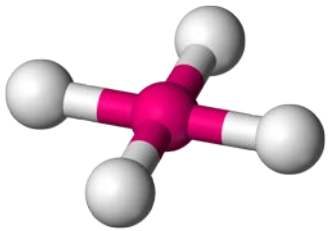
Δ-$[Fe(ox)_3]^{3-}$

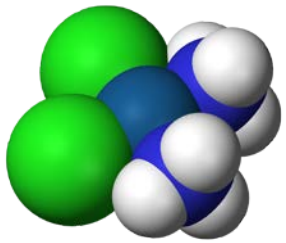


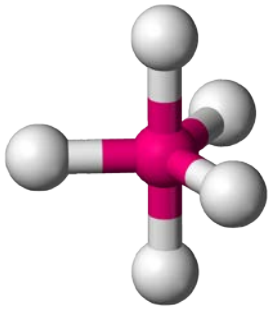
Λ-*cis*-$[CoCl_2(en)_2]^+$

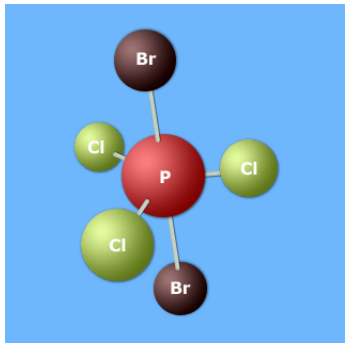


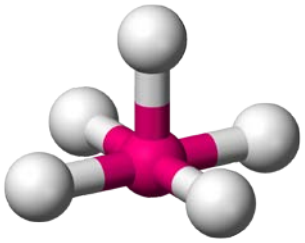
Δ-*cis*-$[CoCl_2(en)_2]^+$

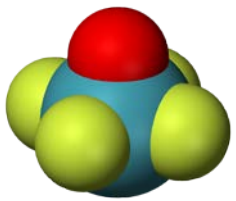










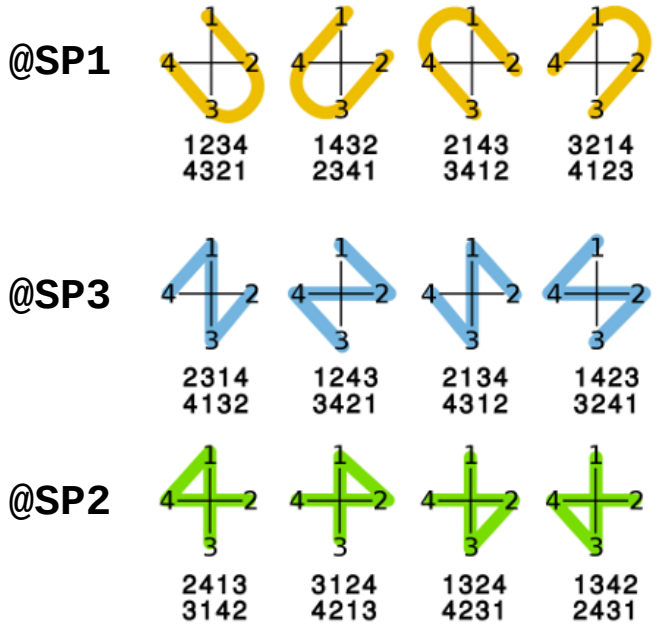


TASK 2: Identify configurations

- There is a labelling scheme that has been documented by OpenSMILES
  - This involves assigning the label for the configuration around a centre based on the order in which the atoms appear in the SMILES string.
- A single square-planar complex can therefore have three different labels according to the order in which the atoms are specified
  - Can this can be extended to the InChI by using the canonical numbering of each atom as its order?

http://opensmiles.org/opensmiles.html

OpenSMILES
Square Planar Centres



Trigonal Bipyramidal Centers

@TB1 - @TB18

Octahedral Centers

@OH1 - @OH28

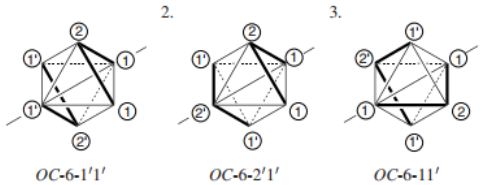
TASK 2: Identify configurations

- OpenSMILES approach not the same as implementing IUPAC nomenclature
  - potentially a harder task that involves assigning Cahn-Ingold-Prelog (CIP) priorities
  - there is code in RDKit to yield the CIP priorities but it isn't accessible via the Python wrapper.
- What effect does priming have if we take the SMILES approach?

IR-9.3.5.3 *Priming convention*

The priming convention is required in order to avoid ambiguity when using the configuration index to describe the stereochemistry of systems that contain either more than one polydentate ligand of a particular kind, or a polydentate ligand that contains more than one coordinating fragment of a particular kind. This situation is found commonly with bis(tridentate) complexes, but also arises in more complicated cases. The need for this convention is best illustrated by example.

Examples:



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