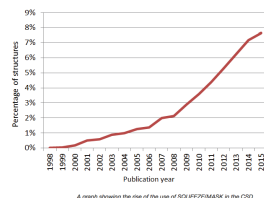
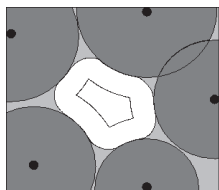


(check)CIF, SHELXL-2014, SQUEEZE



Ton Spek
Utrecht University
The Netherlands

SHELX Workshop, ACA-Denver, July 22, 2016

The CIF Standard & Validation

- CIF was **created around 1990** by an IUCr committee for **data exchange and archival**.
- One of the early adopters was SHELXL97.
- Acta Cryst. C pioneered its use for publication data and text entry.
- Acta Cryst. C pioneered **automated checking** of data consistency and data completeness.
- Today, an **IUCr-checkCIF report** is an essential requirement for publication in **most journals**.

FCF-Validation Added

- A SHELX97 style CIF **only reports** the numerical results of a structure determination (i.e. Space group, model parameters and R-values)
- The associated 'CIF-style' FCF file allows for a detailed analysis of the fit of the structure model (Fcalc) to the reflection data (Fobs)
- Together, the CIF + FCF offer **the authors interpretation of the experimental data**

Archival of the Experimental Data

- For a **proper review** and **archival** for possible follow-up research we would need at least the deposition of the **unmerged reflection data**.
- Needed to **resolve issues** concerning missed symmetry, missed twinning, hydrogen atoms, main molecule disorder, disordered solvents etc.
- The '**embedding**' mechanism was chosen to include the **unmerged reflection data** in the CIF as a comment with a proper data name, to be ignored in most applications such as graphics and geometry calculations.

Final .res & .hkl Embedding

- Two general data names were introduced for the inclusion of the refinement and reflection details `_iucr_refine_instructions_details` and `_iucr_refine_reflections_details` resp.
- The .res and .hkl are embedded as text between semicolons (i.e. '`<newline> <text> <newline>` ;')
- SHELXL2014 introduced its own equivalents: `_shelx_res_file` & `_shelx_hkl_file` along with associated `checksums` for data integrity.
- Those embedded data should NOT be edited or removed from the CIF.
- Use 'shredcif' or PLATON to extract the .res & .hkl

The SHELXL2014 ABIN Instruction

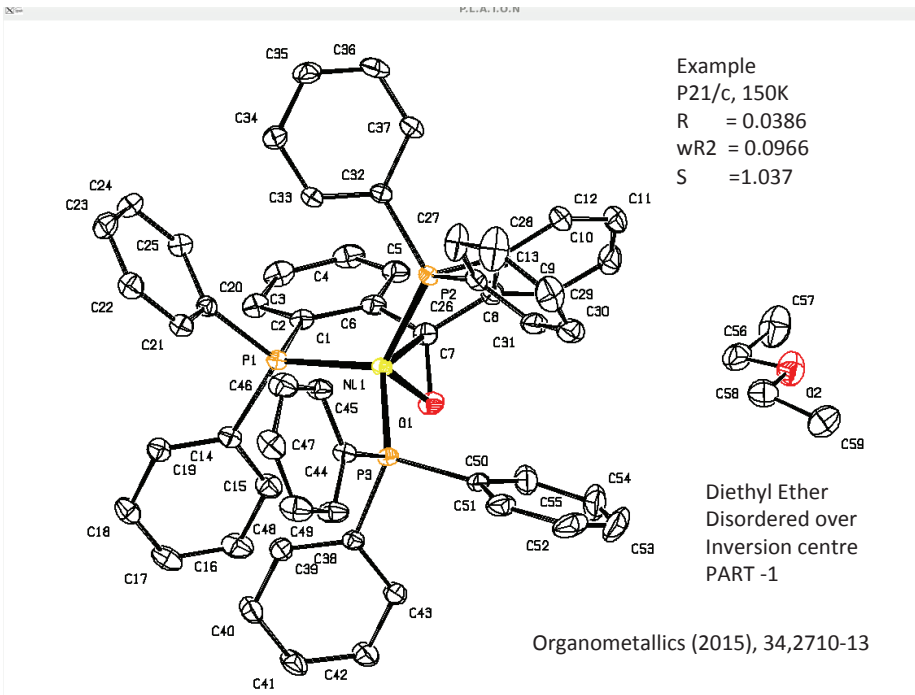
- The **total electron density** in the unit cell can be **split** up into two parts, **rho1 & rho2**, with associated contributions to $F_h(\text{calc})$: $F_h(\text{calc}) = F_{h1} + F_{h2}$.
- F_{h1} might be associated with the **main molecule** of interest and F_{h2} with a **disordered solvent region**.
- Generally, a **disorder model** takes care of F_{h2} .
- **Optionally**, the F_{h2} part can be calculated using an **external program** and read by SHELXL from a **.fab file**
- The **ABIN** instruction informs SHELXL2014 to search for and read the external .fab file with H,K,L,A_h2,B_h2.

The Disordered Solvent Problem

- SHELXL2014 offers an **extensive set of options** to model and **refine disordered solvents**. This is the **preferred approach** in most **known solvent disorder** cases.
- In cases of multiple **unknown solvent mixtures** and **smear density**, an elaborate disorder model might not work satisfactorily.
- In such cases the **SQUEEZE approach** with an externally determined solvent contribution might result in a **satisfactory main molecule refinement**

PLATON/SQUEEZE

- The current implementation of the SQUEEZE tool to handle disordered solvents is the **third generation** of a method published by us more than 25 years ago.
- Interfacing with **SHELXL2014** refinement solves many earlier issues with SHELX76 & SHELXL97 using .res & .hkl data. [e.g. Modification of the observed data]
- **Documentation of the recommended procedure:** A.L.Spek (2015) Acta Cryst. C71, 9-18
- http://www.platonsoft.nl/PLATON_HOW_TO.pdf
- **Example:** Comparison of disorder model <> SQUEEZE



PLATON

A Multipurpose Crystallographic Tool

(C) 1980-2016 A.L.Spek - Version: 150716 [WEB:Jul 12, 2016]

GRAPHICS	GEOM-CALC	VOIDS FLIP	SYMMETRY	ABSORPTION	REPORT	MISC-TOOLS
PlutonAuto	Calc All	Calc Solv	Addsym	MULscanABS	Validation	System-S
Ortep-Plot	Calc Intra	Calc K.P.I	Addsym-EQL	ABSPstScan	Asym-VLew	fcf2hkl
NewmanPlot	Calc Inter	Squeeze	Addsym-EXT	ABSTempa	FCF-Valld	Expand2P1
Ring-Plots	Calc Coord	Hybrid	Addsym-PLT	ABSGauss	DLfFourler	FCF-Gener
Plane-Plot	Calc Metal	CalcFCFsqd	Addsym-SHX	ABSXtal	ANALofVAR	HKLF-Gener
Polyhedra	Calc Geom	Contoursqd	Newsym	ABSSphere	ByvoetPair	HKL-Transf
ContourDf	Calc Hbond	Solv F3D	Nonsym	ShxAbs	Asym-Expct	Exor-Res
Contour-Fo	Calc TMA	Solv Plot	LePage	AnomDlsVal	Asym-Valld	Anls-Res
AutoMolFlt	L.S.-Plane	CavltypPlot	DelRed	AnomDlsPlt	SupplMater	Rename-Res
hkl2Powder	DLhedAngle	WllsonPlot	Molsym	MuPlot	Expect-hkl	Auto-Renum
SlmPowderP	AngleLines	Fltp Menu	SPGRfromEX		CSD-Cell	Create-spf
RaddlstFun	AngLsplLn	Fltp Show	Asym		CSD-Quest	Create-res
Patterson	CremerPapL	Fltp Patt	ASYMaverFA		StructLDy	Create-clf
ShelxtPlot	BondValenc	Fltpper 25	LePageTwn	XtlPLanAgl	StralnAnal	Create-pdb
PlutONatlv	HFlx - res	Structure?	TwnRatMat	Xtal Hablt	LaccCIF-acc	clf2shelxl

- PLA-SP2 12
- OptionMenu
- Print-Level
- EPS-Listing
- PDF-Listing
- PageHeader
- NoMolFitInv
- KeepMon-I-n
- NoExpand
- FCF-Calc
- PNG
- RefLlisting
- DebugOutput
- SetWindSize
- Portrait
- GenerStnMx
- GenerRandom
- EPS HPGL
- Auto-Plot
- K-LineWidth
- Reverse-B&W
- Browser
- Reset End

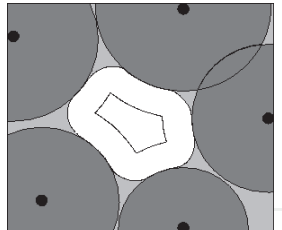
Xtal Data (CIF14) x.clf- Set 1(1): I
RefL Data (LIST4) x.fcf [FCF] (1): I

Browser - HELP

<https://www.platonsoft.nl/PLATON-MANUAL.pdf> <https://www.platonsoft.nl/PLATON-HOW-TO.pdf>

Search for and Analysis of Solvent Accessible Voids In the Structure

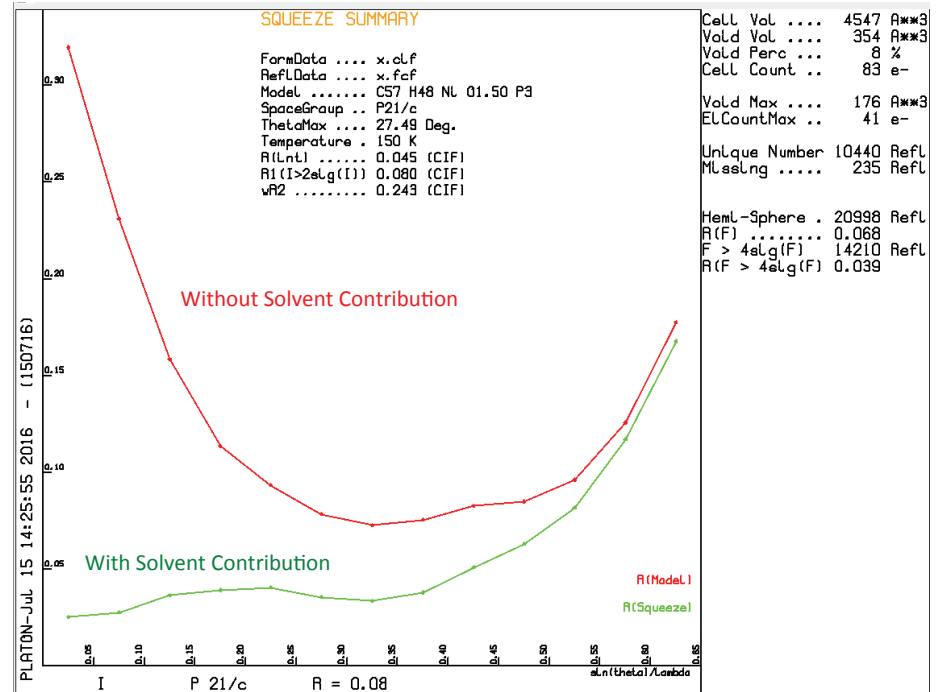
Area	#GrdPt	VolPerc.	Vol(A ³)	X(av)	Y(av)	Z(av)	ELgenvecotr(frac)	Slg(Ang)
1	22574	[3803]	4 177	[29.8]	0.500-0.000	0.500	-0.508 1.000 0.708	2.38
2	22577	[3803]	4 177	[29.8]	0.500 0.500	1.000	1.000 -0.975 1.000	1.49
							0.309 0.164 -0.311	2.58
							0.357 0.000 -0.705	1.48
							1.000 -0.159 0.317	1.22



Definition of VOIDS (white area): roll sphere with radius 1.2 Å
In this case there are two solvent accessible voids with Volume 177 Å³ in the unit cell
SQUEEZE uses this area as a mask to recover the density
In the white area from the difference density map by iterative back-Fourier transformation into F_h2 (.fab)

PLATON/SQUEEZE

Cycle	R(F)	Nref(Heml)	R(F)>4*slg(F)	Nref	EL (Solv)/Cell
1	0.109	20998	0.076	14210	0
2	0.069	20998	0.040	14210	70
3	0.068	20998	0.039	14210	82
4	0.068	20998	0.039	14210	83
5	0.068	20998	0.039	14210	83



S U M M A R Y

== Total (Fa-Fc)map Electron Count Outside Voids = 0

=====
HOW TO PROCEED with L.S. refinement after running SQUEEZE:
=====

SHELXL2014: Continue refinement in the presence of the three files name_sq.lns, name_sq.hkl & name_sq.fab
Additional info on name_sq.sqf, name_sq.sqz & name_sq.lls

=====
Citation: Spek, A.L. (2015). Acta Cryst. C71, 9-18.
=====

- The _sq.ins file is the original .res (from .cif) + ABIN Instruction
- The _sq.hkl file is the original .hkl (from .cif)
- The _sq.fab file (created by SQUEEZE) includes after the last reflection info about the SQUEEZE job i.e. _sq.sqf & _sq.sqz

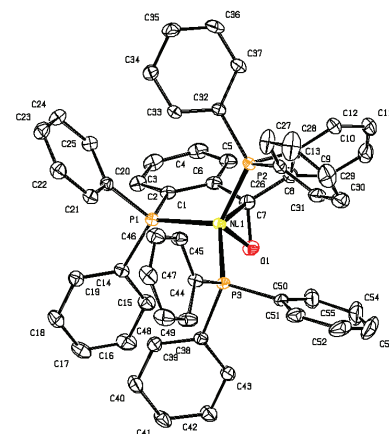
Note: PLATON/SQUEEZE does NOT refine the Model Parameters

Comparison

$R_1 = 0.0386$, $wR_2 = 0.0966$

S = 1.037, 42 electrons

C-C BP = 0.0036 Angstrom

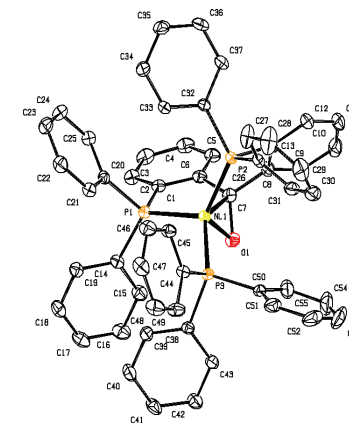


Disorder Model Diethyl Ether

$R_1 = 0.0383$, $wR_2 = 0.0960$

S = 1.044, 41 electrons

C-C BP = 0.0035 Angstrom



Squeeze Model Diethyl Ether

The Proper use of the SQUEEZE Tool

- It is important that the final CIF archives both the details of the SQUEEZE calculation and the unmerged reflection data.
- The SQUEEZE details are appended to the .fab file
- SHELXL2014 offers, by embedding the .res, .hkl & .fab data, all what is needed for that.
- In that way, the calculations can be reconstructed and/or alternative refinement models attempted.

Summary of SQUEEZE + SHELXL2014

1. Refine a non-solvent model with **name.ins** & **name.hkl** (Include ACTA record, **NO LIST 6**).
2. Run PLATON/SQUEEZE, based on **name.cif** & **name.fcf** from **1** as '**platon -q name.cif**'.
3. Continue SHELXL refinement with the files **name_sq.ins**, **name_sq.hkl** & **name_sq.fab** from **2** as '**(shel)xl name_sq**'
4. Inspect the **.lis** & **.lst** files and Validate

SQUEEZE Disordered Solvent + Twinning

- **Step 1:** SHELXL2014 refinement based a **name.ins** (that should include 'ACTA', 'LIST 8', 'BASf' and 'HKLF 5' [or 'TWIN'] records) and a **name.hkl** file
- **Step 2:** Run SQUEEZE with the **name.cif** and **name.fcf** files produced in **Step 1** (i.e. run: `platon -q name.cif`)
- **Step 3:** Continue SHELXL refinement with the files **name_sq.ins**, **name_sq.hkl** and **name_sq.fab** produced by PLATON in **step 2** → **name_sq.cif** & **name_sq.fcf**

SQUEEZE-2016 EXAMPLE [Chem.Eur.J. (2015) 21, 1765]

Acetonitril Model: $R = 0.0323$, $wR2 = 0.0889$, $\rho(\max) = 1.34 \text{ e/A}^{-3}$

Space Group $P2_1$

$Z = 4$, $Z' = 2$

60:40 Twin

Twin axis: (0 0 1)

150 K

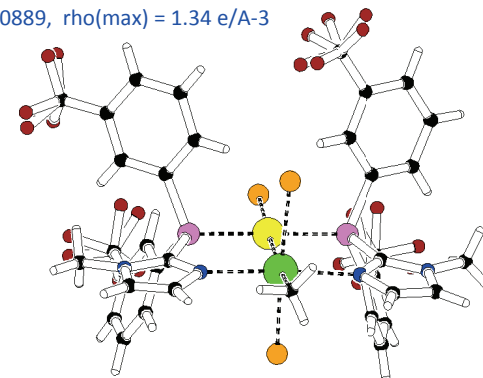
TWINABS hklf5 data

Acetonitril solvate

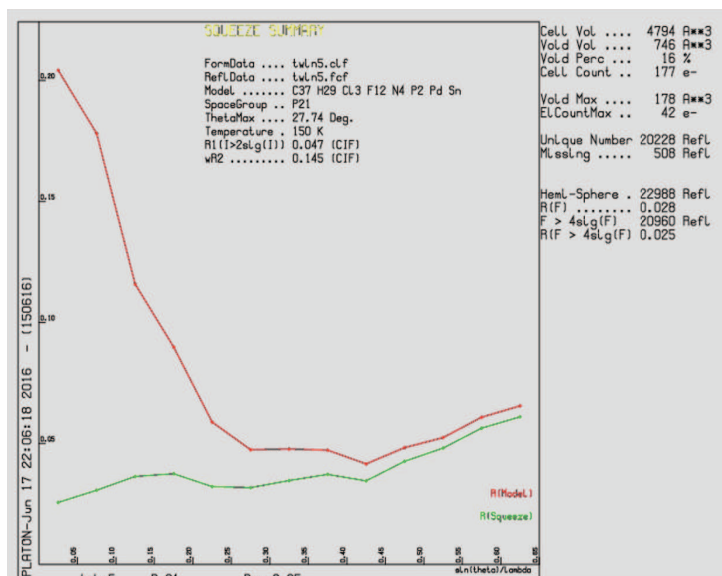
Step 1 (SHELXL2014) → $R1 = 0.047$, $wR2 = 0.1445$

Step 2 (SQUEEZE) → 177 electrons found in unit cell

Step 3 (SHELXL2014) → $R1 = 0.0275$, $wR2 = 0.0679$, $S = 1.064$



Effect of on $R(F)$ before and after SQUEEZE as a function of $\sin(\theta)/\lambda$

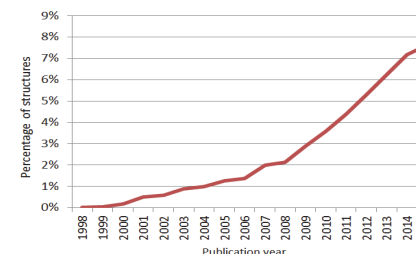


Requirements

- There should be **no residual unresolved density** in the discrete model region of the structure because of its impact on the difference map in the solvent region. (may invalidate el. Count)
- The data set should be **reasonably complete** and with **sufficient resolution** [i.e. $\sin(\theta)/\lambda > 0.6$].
- There should be no **unresolved charge balance** issues that might effect the chemistry involved (e.g. The valency of a metal in the ordered part of the structure)

Limitations

- The reported **electron count** in the solvent region is meaningful only with the supply of a complete and reliable reflection data set.
- The SQUEEZE technique can not handle properly cases of **coupled disorder** effecting both the model and the solvent region.
- The solvent region is assumed not to contain significant anomalous scatterers (**Friedels averaged**)



A graph showing the rise of the use of SQUEEZE/MASK in the CSD

Reported SQUEEZE
Usage Statistics as
Prepared by the CCDC

Thank you !

a.l.spek@uu.nl

[More info:www.platonsoft.nl](http://www.platonsoft.nl)

(including this powerpoint presentation)