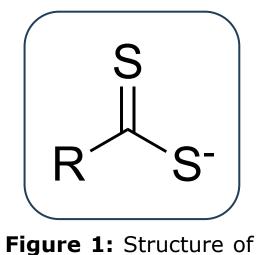


# Synthetic Exploration making Aryl-Dithiocarboxylate Salts

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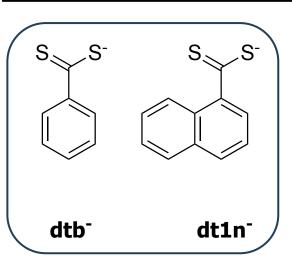


### Introduction



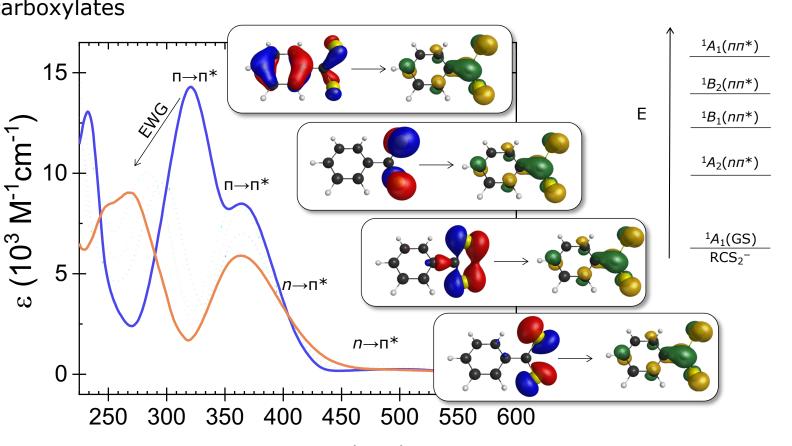
Dithiocarboxylates (dtc) are a class of compound that contains the dithiocarboxylate functional group (-CS<sub>2</sub>-)

- Absorb light throughout the UV and visible regions of the spectrum due to  $-CS_2^$ localized transitions
- Are isolable as organic soluble salts



Aryl-dithiocarboxylates like dithiobenzoate (dtb<sup>-</sup>) and 1-dithionaphthoate (dt1n<sup>-</sup>) have additional electronic states due to electronic coupling of the aryl and  $-CS_2^-\pi$ -systems

aryl-dithiocarboxylates



### wavelength (nm)

Figure 3. Experimental electronic absorption spectra for various substituted aryl dithiocarboxylates. Natural transition orbital isosurfaces are plotted for the 4 lowest excited electronic states, from TD-CAM-B3LYP/def2-TZVPD/CPCM(EtOH). The Jabłonski diagram illustrates the relative state energies identified with their molecular terms (using  $C_{2v}$  point

 The energy of the 3 lowest electronic transitions is insensitive to the substituents *para*- to the dithiocarboxylate group

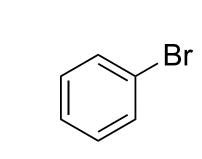
The synthesis of dithiocarboxylates aims to support:

- Developing methods for creating new aryl-CS<sub>2</sub><sup>-</sup> compounds
- Characterization of new aryl dithiocarboxylates via NMR, UV-Visible spectrophotometry, IR spectroscopy and ESI mass spectrometry
- Provide experimental data for benchmarking computational methods used to simulate spectra

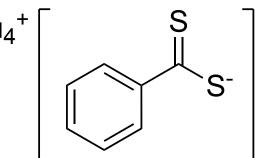
# General Synthetic Procedures

- Synthesis for dithiocarboxylates uses a nucleophilic addition to CS<sub>2</sub> by a Grignard reagent
- Organic soluble salts were obtained and isolated by the addition of NBu<sub>4</sub>+ or PBzPPh<sub>3</sub>+

**Scheme 1.** General synthetic procedure utilized in formation of aryl-DTC compounds.



1) Mg<sup>0</sup>, THF(reflux) NBu<sub>4</sub><sup>+</sup> 2) CS<sub>2</sub>, 0°C 3) Aq. Workup 4) [NBu<sub>4</sub>]Br



R • All syntheses started with commercially available, substituted aryl halides

• Fully characterized compounds include ortho- and para- substituents have been made, with majority of synthetic procedures following this method.

dtb2,4,6R

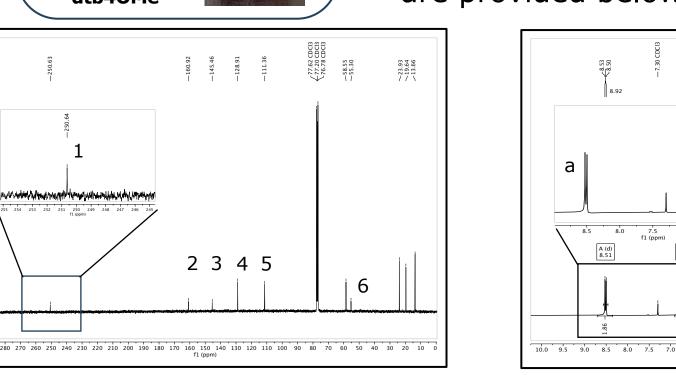
 The salts of DTCs were purified using recrystallization and/or reprecipitation

# Characterization and Discussion



characterized using <sup>1</sup>H- and <sup>13</sup>C-NMR, IR, UV-Visible spectrometry

Example spectra of [NBu<sub>4</sub>][dtb4OMe] are provided below



[NBu4][dtb4OMe] in 1 mL CDCl3 with 8 mg [Cr(acac)<sub>3</sub>] in as a spin-relaxation agent. 1) describes the carbon peak for CS<sub>2</sub> group,

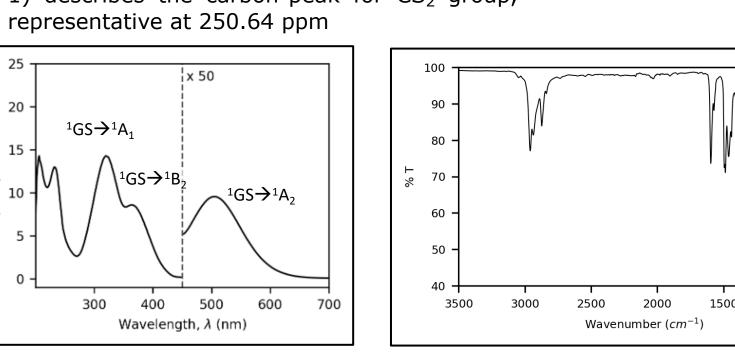
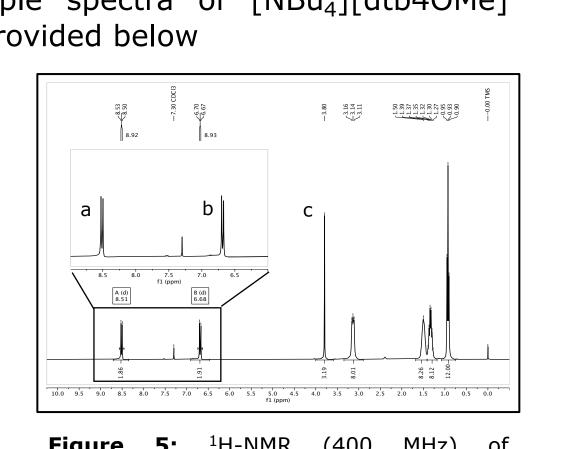
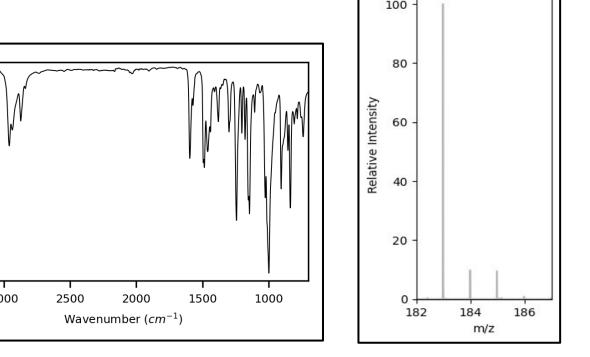


Figure 6: Electronic absorption spectrum of [NBu<sub>4</sub>][dtb4OMe] in



[NBu4][dtb4OMe] in CDCl3. The inset is of the aromatic region



[NBu<sub>4</sub>][dtb4OMe]. Large absorbtion at pattern for dtb4OMe<sup>-</sup> 999.0 and 1596.0 cm<sup>-1</sup> correlates with from ESI(-) mass CS<sub>2</sub> and aromatic bond excitation spectrometry

**Table 1.** Spectroscopic and physical characteristics of synthesized dithiocarboxylate salts

	Compound	λ <sub>max</sub> (A <sub>1</sub> , B <sub>2</sub> , A <sub>2</sub> )	CS <sub>2</sub> <sup>13</sup> C (ppm)	Computed exact mass (AMU)	Determined exact mass (AMU)	Yield (%)	Color	Referenc
а	dtb⁻	286, 361, 504	253.24	152.9838	152.9790	54	Black	2
b	dt1n-	-, 347, 485	257.44	202.9995	-	54.2	Persimmon	2
C	dt2n-	-, 356, 509	252.56	202.9995	202.9935	73.0	Eggplant	2
d	dtb4Me⁻	296, 363, 505	260.07	166.9995	-	71.9	Crimson	2
e	dtb2Me <sup>-</sup>	209, 348, 500	259.81	166.9995	-	24.4	Orange	-
f	dtb2,4Me <sup>-</sup>	-, 348, 503	260.01	181.0151	-	2.6	Peach	-
g	dtb2,6Me <sup>-</sup>	-, 350, 498	260.52	181.0151	-	37.3	Peach	-
h	dtb2,4,6Me <sup>-</sup>	214, 350, 501	261.29	195.0308	-	18.0	Peach	3
i	dtb2,4,6iPr-	211, 346, 479	262.12	279.1247	-	15.5	Peach	3
j	dtb4OMe-	321, 363, 507	250.64	182.9944	182.9879	46.8	Raisin	2
k	dtb2Me4OMe <sup>-</sup>	-, 349, 507	259.41	197.0100	-	36.3	Grapefruit	-
I	dtb2OMe4Me <sup>-</sup>	235, 349, 503	255.65	197.0100	-	59.1	Tangerine	-
m	dtb2OMe <sup>-</sup>	-, 349, 499	255.35	182.9944	-	6.0	Crimson	-
n	dtb2,40Me <sup>-</sup>	305, 350, 507	254.93	213.0050	-	7.6	Peach	-
0	dtb4F-	291, 365, 520	-	170.9744	-	53.2	Plum	2
р	dtbCF <sub>3</sub> -	267, 363, 520	251.66	220.9712	-	1.3	Brown	2

#### **Qualitative Observations**

- The formation of the Grignard and addition of CS<sub>2</sub> varies with electron donating and bulky substituents
- Aryl halides substituted with electron withdrawing groups reacted quicker to form the Grignard, while addition to CS<sub>2</sub> took longer
- EDGs slow formation of the Grignard, with a faster addition to CS<sub>2</sub>
- Both the formation of the Grignard and the addition of CS<sub>2</sub> are slower for sterically hindered aryl halides

# Challenging Aromatic Systems

Aryl-halides with electron withdrawing substitutions react quickly with magnesium to form Grignards<sup>4</sup>

dtb2,4,6iPr

dtb20Me4Me

dtb4CF<sub>3</sub>

Synthetic Library of Aryl-DTCs

**Chart 1.** Series of dithiocarboxylate compounds isolated as NBu<sub>4</sub>+ salts

dtb2,4,6Me<sup>-</sup>

\* Compounds were paired with BzPPh<sub>3</sub>+

dtb2,6Me

- The resulting Aryl-MgX is a weaker nucleophile toward electrophiles like CS<sub>2</sub>
- Side reactions like the formation of the substituted biphenyls compete with addition of CS<sub>2</sub><sup>5</sup>
- A canonical example, BrMgPh4CF3, readily forms F<sub>3</sub>CPhPhCF<sub>3</sub>

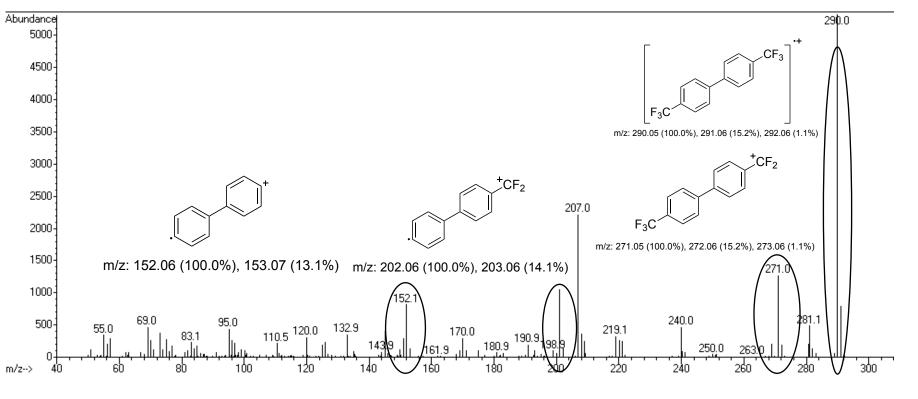
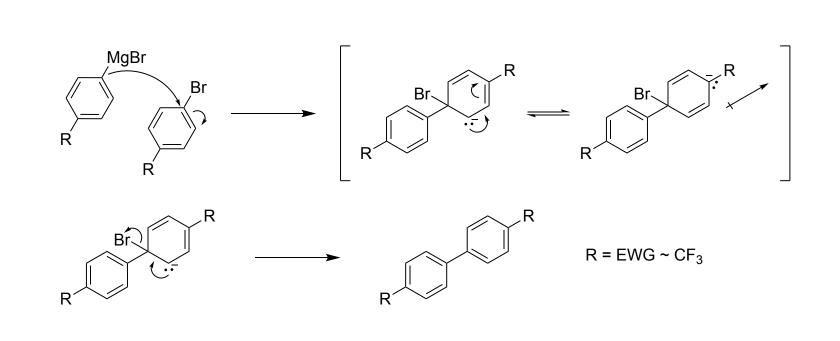


Figure 9. Mass spectrum from the separated organic layer produced during work up of a failed attempt to synthesize dtb4CF<sub>3</sub>-

- Conditions were altered to reduce byproducts:
- Temperature of Grignard formation reduced to 35.0°C for 4
- CS<sub>2</sub> addition step extended to 3 hours at 0 °C
- Extended CS<sub>2</sub> addition for up to 20 hours did not improve yields beyond 1.3%

**Scheme 2.** Speculative mechanism of formation of the undesired dimer, stabilized by EWGs



- The aryl-Grignard formation proceeded in high yield using "Turbo Grignard
- Aryl-dicarboxylates with fluorine at the ortho position were not

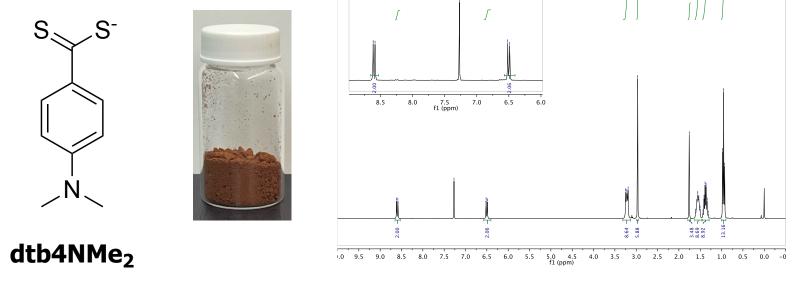
Scheme 3. Synthesis to validate the formation

of the Grignard reagent via product analysis 1) iPrMgCl·LiCl, -78°C 2) Benzaldehyde 3) Ag. Workup

**Figure 10.** <sup>1</sup>H-NMR (left) and <sup>19</sup>F-NMR (right) of a-(2′,6′-difluorodiphenyl)benzyl alcohol obtained in 66.2% yield. Solvent = CDCl<sub>3</sub>

1.0 9.5 9.0 8.5 8.0 7.5 7.0 6.5 6.0 5.5 5.0 4.5 4.0 3.5 3.0 2.5 2.0 1.5 1.0 0.5 0.0 -0 11 (ppm)

- equilibrium involving the dimethylamine substituent dtb4NMe<sub>2</sub> complicated isolation  $[NBu_4][dtb4NMe_2].$
- In the <sup>1</sup>H-NMR, the singlet at ca. 3 ppm is consistent with methyl groups on a protonated amine, NHR<sub>3</sub><sup>+</sup>



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Anika Kumar

AJ Kinsella-Johnson

Isabella Landeros

10 0 -10 -20 -30 -40 -50 -60 -70 -80 -90 -100 -110 -120 -130 -140 -150 -160 -170 -180 -190 -200 -210 -110 (ppm)

Figure 11. Structure and image of attempted [NBu<sub>4</sub>][dtb4NMe<sub>2</sub>], and <sup>1</sup>H-NMR spectrum in CDCl<sub>3</sub>.

### Conclusions

### **General Experimental Methods:**

- The synthesis of organic soluble aryl-dithiocarboxylate salts was adapted to prepare a variety of substituted-aryl systems
- ¹H-NMR, ¹³C-NMR, UV-Vis, IR, and mass spectrometry have been obtained to confirm identity and purity of the compounds

### **Challenging Aromatics:**

- Reaction optimization needs to occur for the formation of an aryl-Grignard and addition of the Grignard to CS<sub>2</sub> for orthofluoro- and trifluoromethyl-substituted aryl compounds
- Isolation procedures need further optimization to account for a substituent group's specific solution chemistry

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