Unravelling Halogen-Bonding Strengths
A Computational Study on Bidentate
Hypervalent Iodine-Based Catalysts

MANCHESTER 1824

Trujillo Research Group
Computationally-led catalyst design

ICHEC
Irish Centre for High-end Computing

Trinity College Dublin
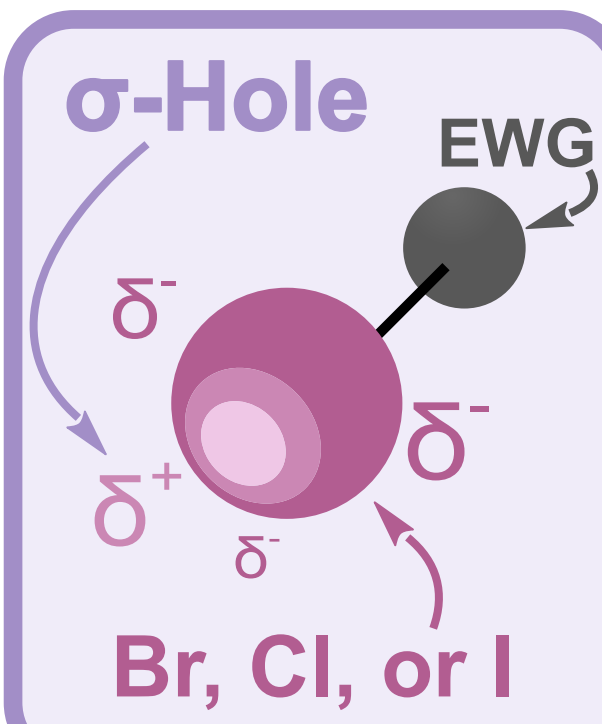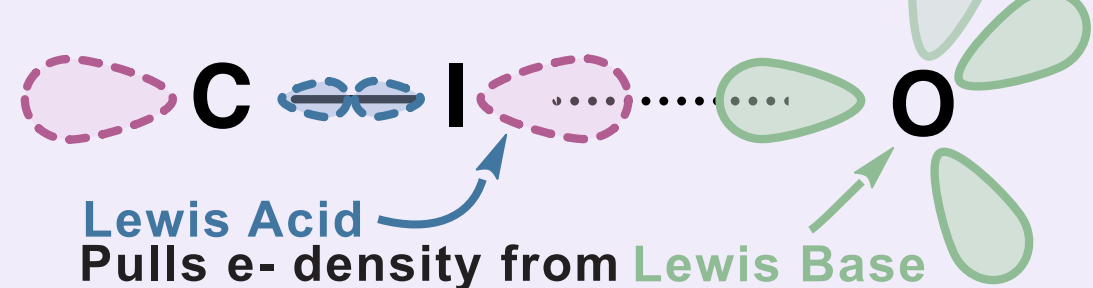Coláiste na Tríonóide, Baile Átha Cliath
The University of Dublin

James O'Brien, Nika Melnyk, Rico Shing Lee, Dr. Michael James, Dr. Cristina Trujillo*

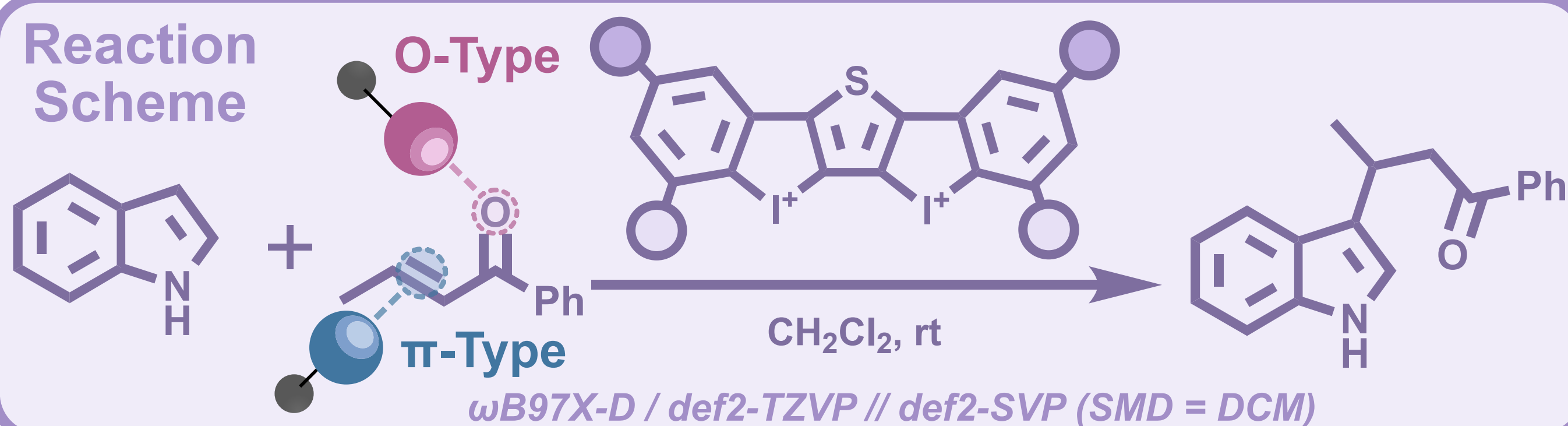*Department of Chemistry, The University of Manchester, Oxford Road, Manchester, M139PL (UK)*
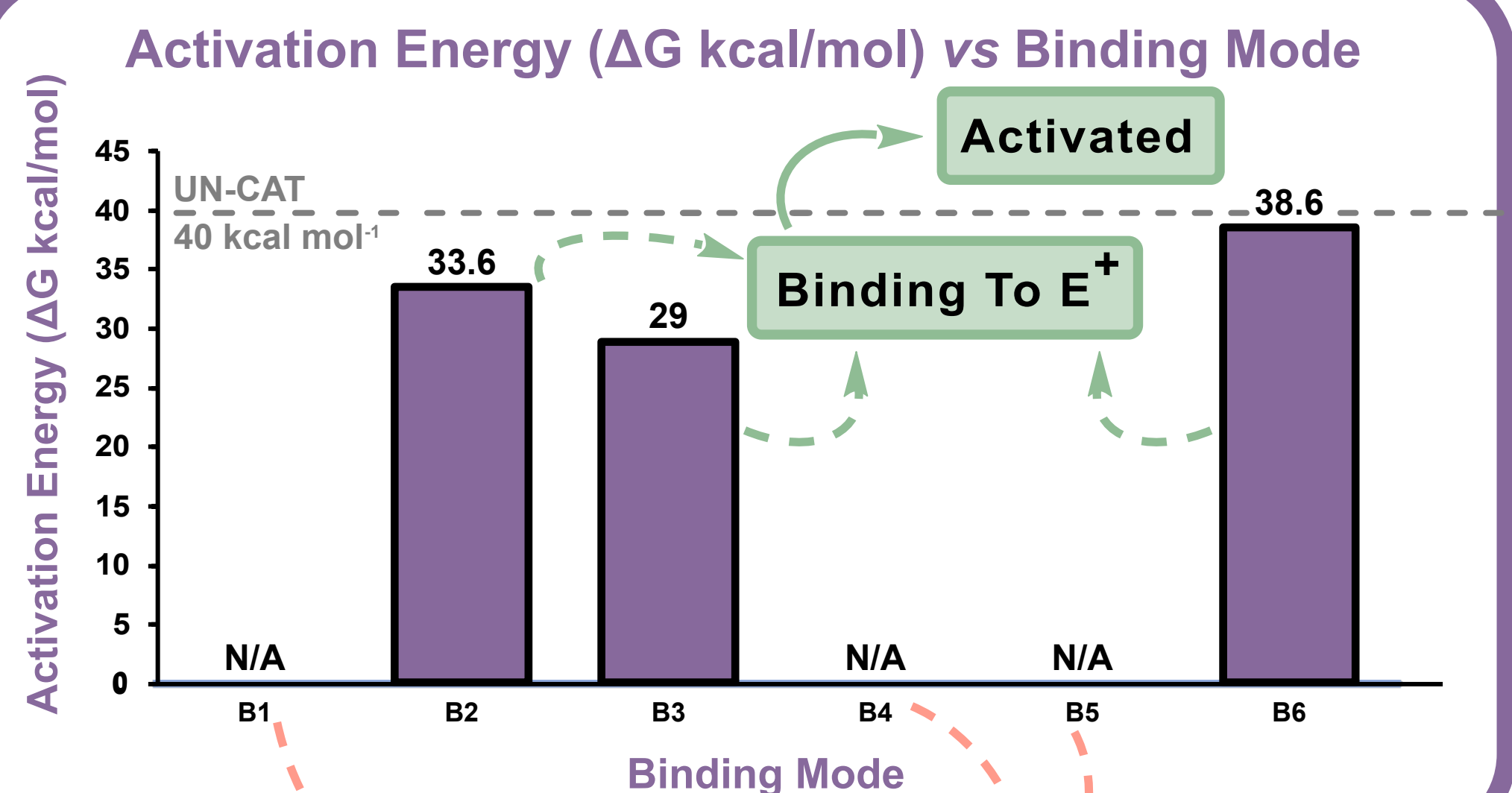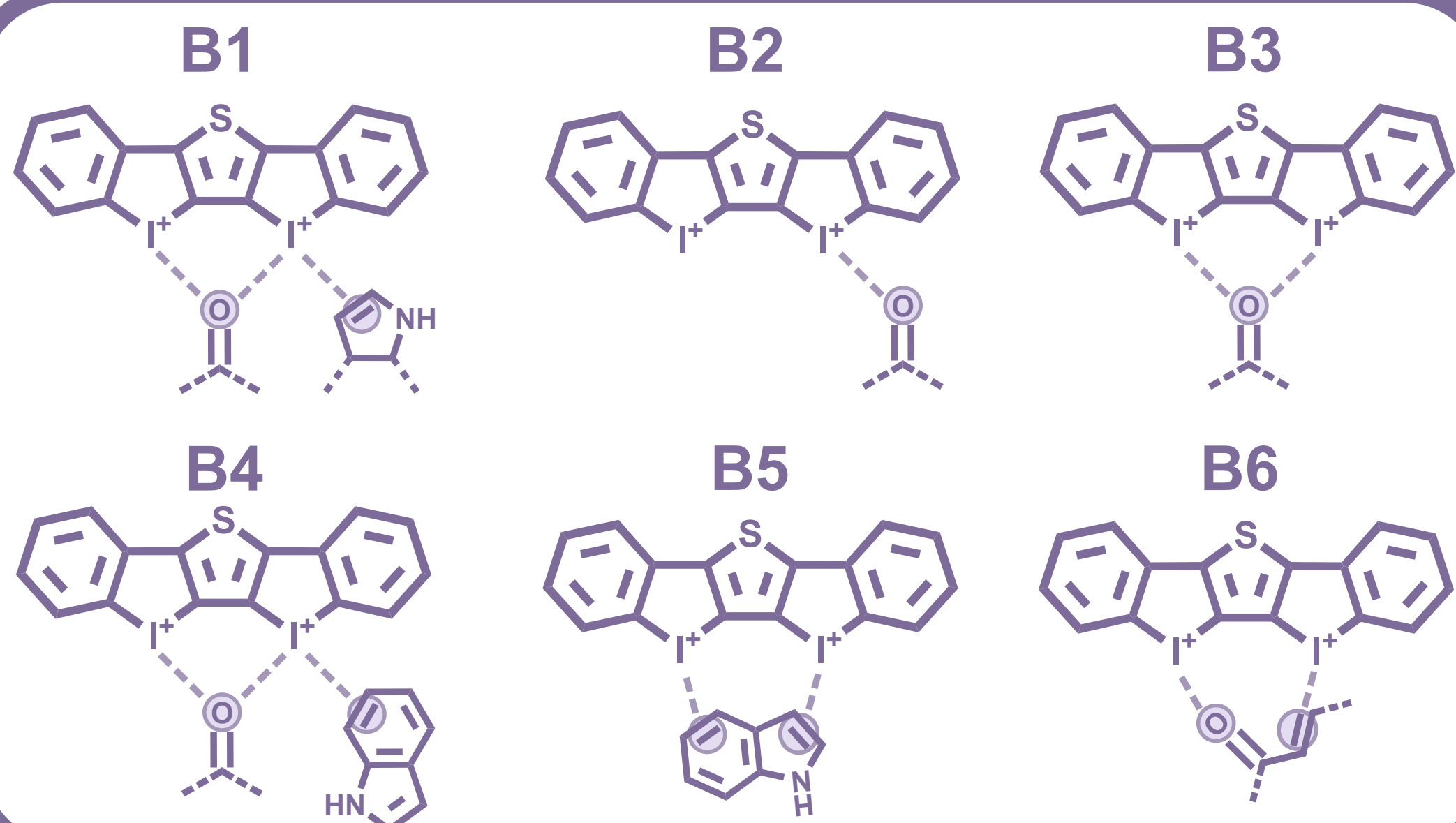
1 Introduction

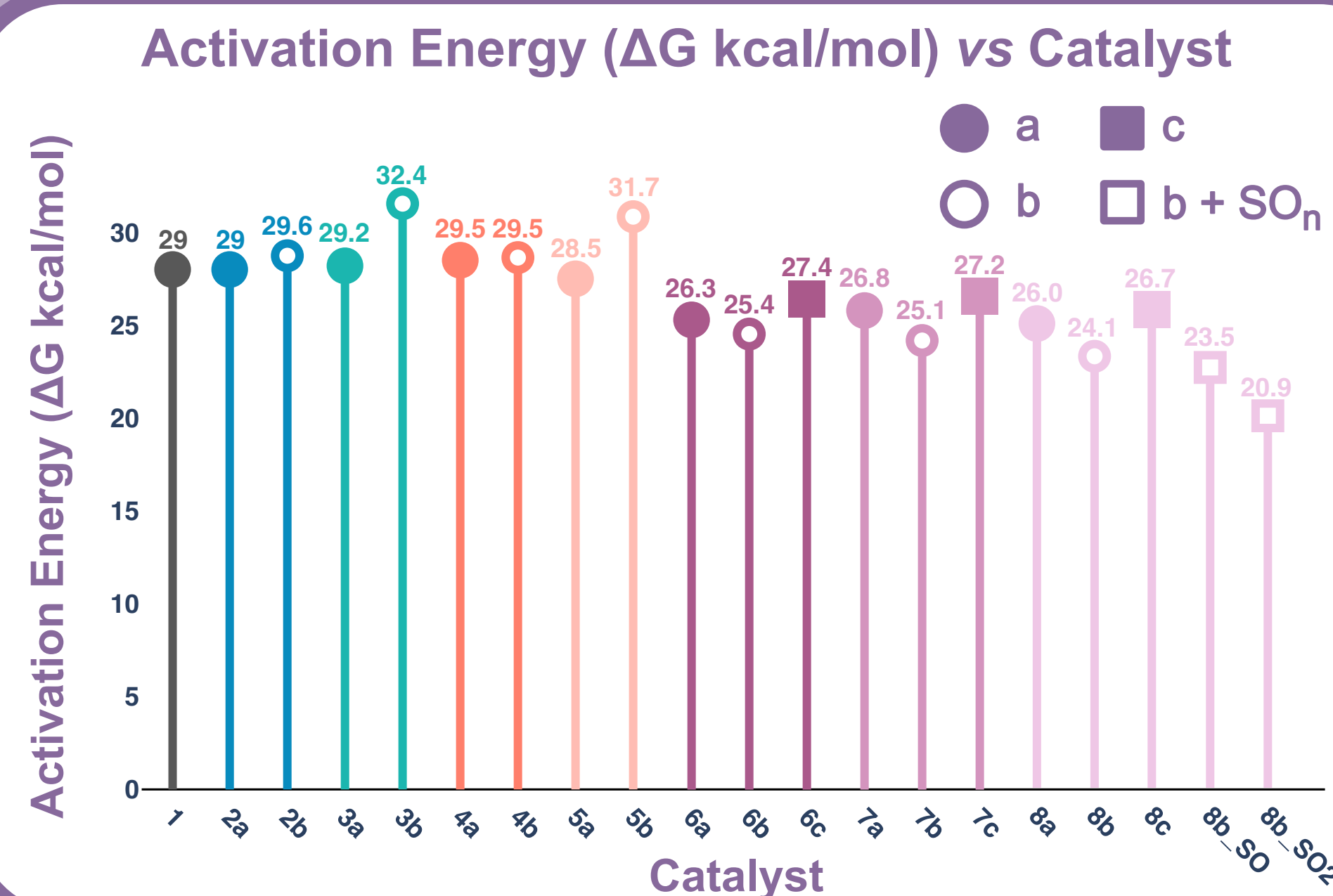**Halogen Bond**
eg. LP (O) → BD* (C-I)

C ⇐⇒ I ·········· O

Lewis Acid
Pulls e- density from Lewis Base

σ-Hole
EWG
δ^-
δ^+
δ^-
δ^-
Br, Cl, or I

Reaction Scheme

O-Type
π-Type
Ph

CH₂Cl₂, rt

ωB97X-D / def2-TZVP // def2-SVP (SMD = DCM)

2 Binding-Mode Investigation

B1   B2   B3
B4   B5   B6

Activation Energy (ΔG kcal/mol) vs Binding Mode

UN-CAT
40 kcal mol⁻¹

33.6 (B2)
29 (B3)
38.6 (B6)
N/A (B1, B4, B5)

Activated
Binding To E⁺
Binding to Nu⁻ → Deactivated

3 Catalyst Functionalisation

E D G
2 — CH₃
3 — tBu

M i x
4 — OH
5 — OMe

E W G
6 — NO₂
7 — CN
8 — CF₃

a — *ortho*
b — +
c — *para*

SO
SO₂

Activation Energy (ΔG kcal/mol) vs Catalyst

- a
- c
- b
- b + SOₙ

Values: 1: 29, 2a: 29, 2b: 29.6, 3a: 29.2, 3b: 32.4, 4a: 29.5, 4b: 29.5, 5a: 28.5, 5b: 31.7, 6a: 26.3, 6b: 25.4, 6c: 27.4, 7a: 26.8, 7b: 25.1, 7c: 27.2, 8a: 26.0, 8b: 24.1, 8c: 26.7, 8b SO: 23.5, 8b SO2: 20.9

4 Interaction Analysis

AIM
C — I⁺ — O
ρ_{BCP}
$\nabla \rho_{BCP}$
Lower ← EDG / EWG → Higher

NBO
LP (O) → BD* (C-I⁺)
C ⇐⇒ I⁺ ·· O
Lower ← EDG / EWG → Higher

Interaction distance
C — I⁺ — O
d_{int}
Longer ← EDG / EWG → Shorter
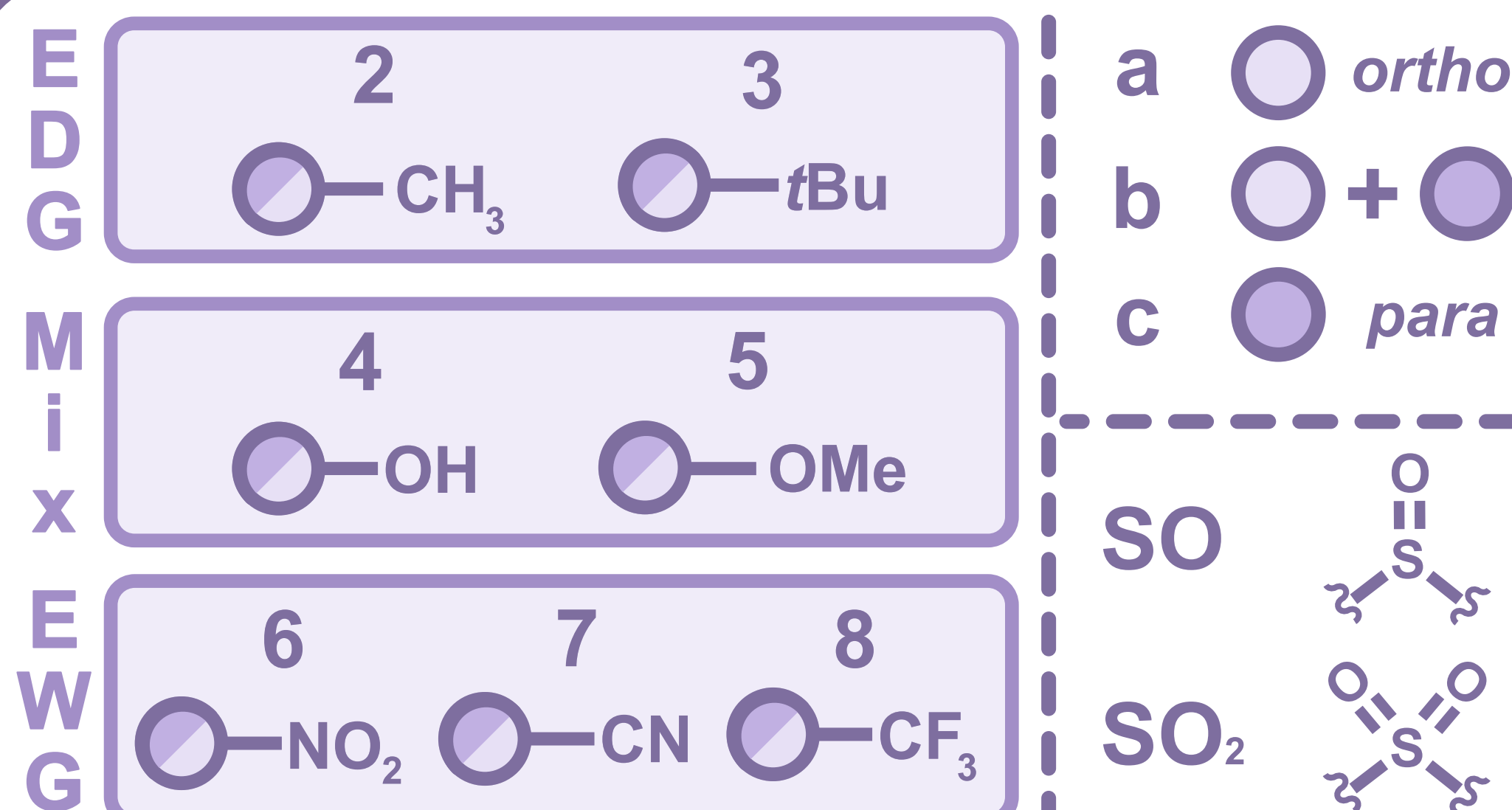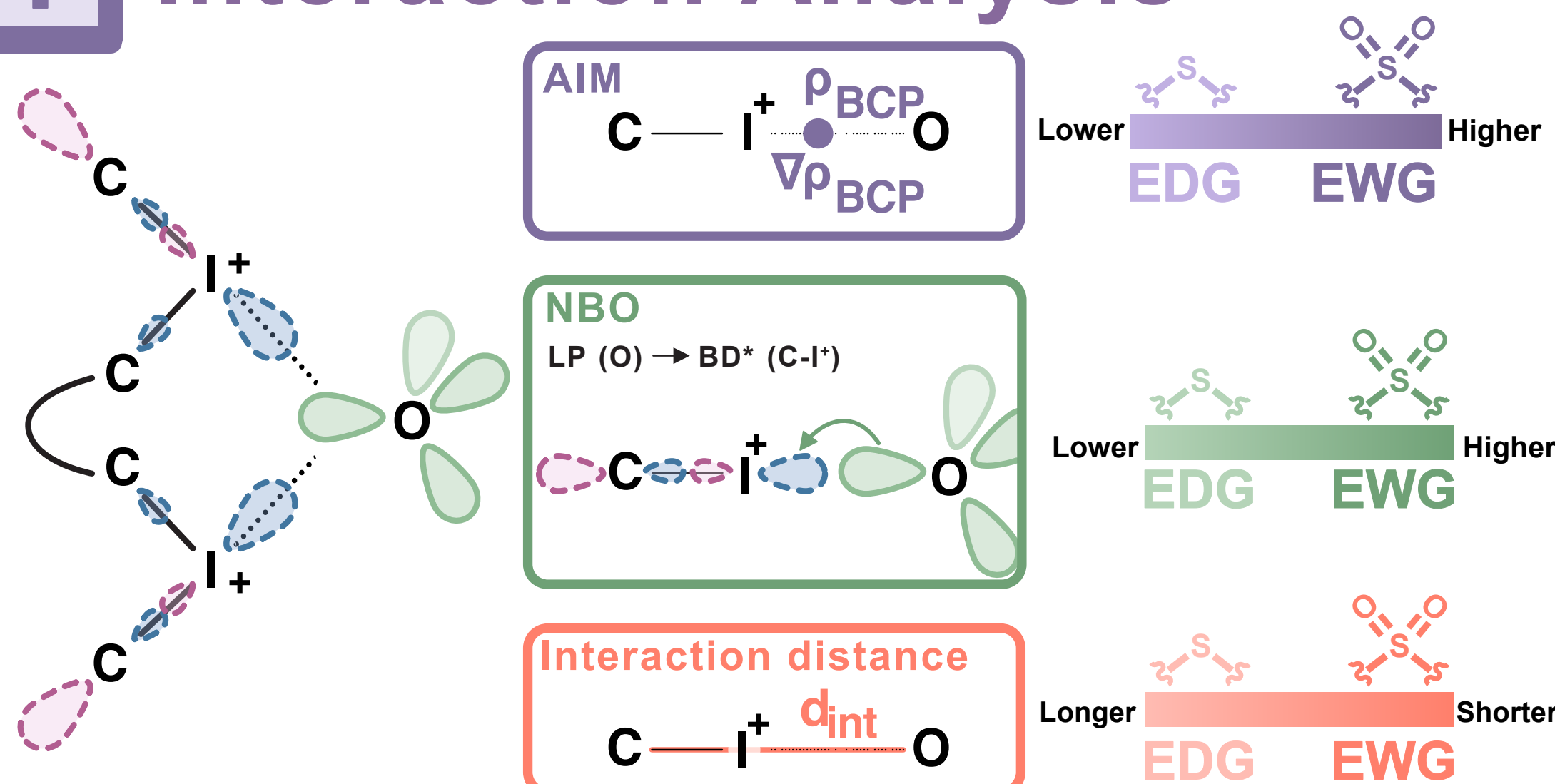
5 Conclusions

Ortho ≈ Para < Ortho + Para

— EDG < — EWG

S < S(=O) < S(=O)₂
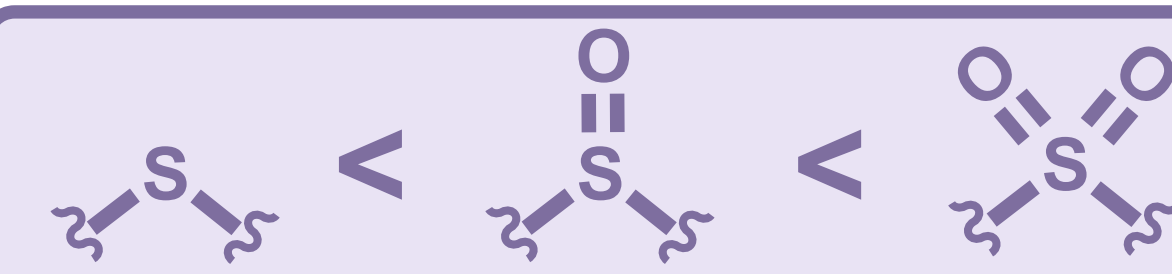
Low $\nabla^2\rho$ + $0 < \rho_{BCP} < 1$
Proves **Non-Covalent Interactions**
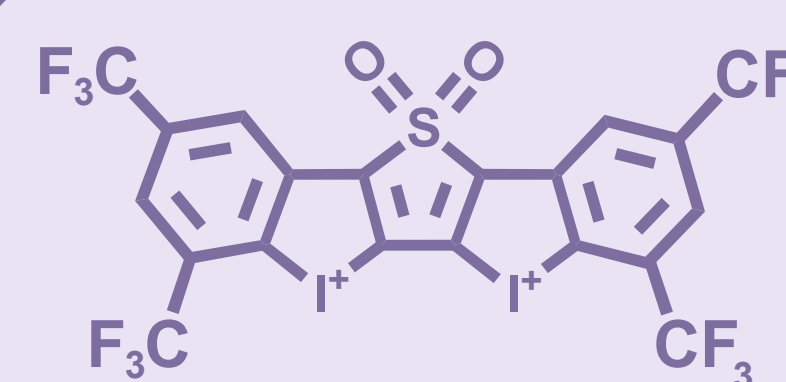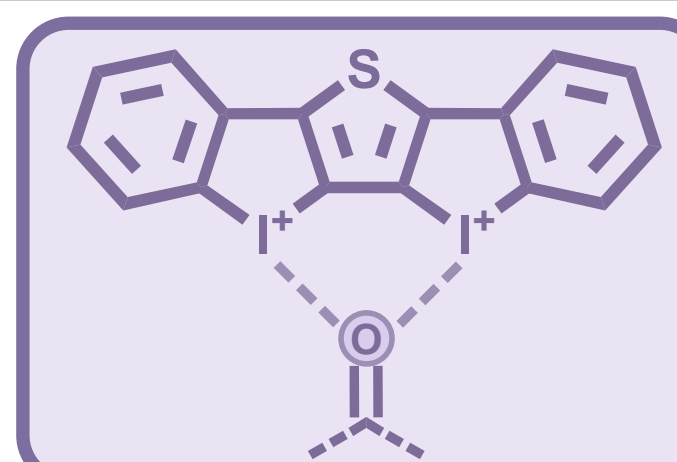
$\Delta G^\ddagger_{UNCAT}$ 40 kcal/mol
$\Delta G^\ddagger_{CAT}$ 20.9 kcal/mol
$\Delta\Delta G^\ddagger$ 19.1 kcal/mol

References

1. F. Heinen, D. L. Reinhard, E. Englage and S. M. Huber, *Angew. Chem. Int. Ed.*, 2021, **60**, 5069–5073.
2. R. Robidas and C. Y. Legault, *Angew. Chem.*, , DOI:10.1002/ange.202301190.
3. N. Melnyk, M. R. Garcia and C. Trujillo, *ACS Catal.*, 2023, 15505–15515.