Supporting Information for

High-pressure reaction profiles and activation volumes of 1,3-cyclohexadiene dimerizations computed by the extreme pressure-polarizable continuum model (XP-PCM)

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3D drawings of TS structures

Figure S1. TS structures and $\Delta H^\ddagger_{298K}$ computed at the ωB97XD/def2-TZVP level of theory.
The XP-PCM method

The XP-PCM is a quantum chemical method aimed to introduce the effects of the pressure on the calculation of the electronic energy $G_{er}$ of a molecular system in a dense medium via a Pauli exchange-repulsion interaction between the molecular system and the external medium. Such a Pauli-exchange repulsion is motivated by the fact that at high pressure, the reduction of the volume of a dense medium forces the intermolecular distances below the van der Waals contacts, in a domain where the intermolecular interactions are dominated by the Pauli exchange-repulsion. In XP-PCM, the external medium (modeling the solvent) is represented as a homogeneous continuum distribution of matter characterized by a static dielectric permittivity $\varepsilon_0$ and a mean electron density $\rho$, as determined by the number of valence electrons of the solvent molecule (Figure 4 in maintext); both parameters depend on the given condition of pressure $p$. The molecular system is accommodated inside a void molecular van der Waals cavity in the external medium (Figure 4). The Pauli exchange-repulsion originates from the overlap between the electron densities of the molecular system and of the external medium in the region of space external to the boundary of this cavity. The Pauli exchange-repulsion corresponds to a step barrier potential located at the boundary of the cavity and with a suitable barrier height $Z_0$. $Z_0$ depends on the electron density $\rho(p)$ of the external medium, and on a semi-empirical parameter $\eta$ that gauges $Z_0$ (a higher value of $\eta$ indicates a harder Pauli barrier potential) by comparison between the computed and experimental equation of states $pV$ for several solvents. The increase of the pressure is modeled by simply shrinking the volume $V_c$ of the cavity hosting the molecular system so as to increase the overlap between the electron densities of the system and of the external medium (Figure 4). The pressure corresponding to a given cavity volume is then determined as the negative of the derivative of the electronic energy $G_{er}$ with respect to the cavity volume $V_c$, $p = -dG_{er}/dV_c$. 
In studying chemical reactions at high pressure, the effective potential energy for
the motion of the nuclei of the reactive system, $G_{\text{tot}}(p)$, corresponds to the electronic
energy $G_{\text{er}}(p)$, supplemented by a contribution of the so-called cavitation Gibbs energy that
contributes to the work necessary to create the void cavity hosting the molecular solute at
the given condition of pressure $p$:

$$G_{\text{tot}}(p) = G_{\text{er}}(p) + G_{\text{cav}}(p).$$  \hspace{1cm} (1)

This work also includes a configurational entropic contribution from the external medium.\textsuperscript{4}

The effective potential energy profile for a reaction at a given pressure $p$ is then
determined by computing $G_{\text{tot}}(p)$ for a set of selected structures along a suitable reaction
coordinate. According to the transition state theory, the activation volume $\Delta V^\ddagger$ is determined
from the slope of the corresponding activation energy $\Delta G_{\text{tot}}^\ddagger(\rho)$ as a function of the
pressure,

$$\Delta V^\ddagger = \frac{\Delta G_{\text{tot}}^\ddagger(p)}{dp}.$$  \hspace{1cm} (2)

In this work, the effective potential energy profile for a reaction at a given pressure
$p$ is then determined by computing $G_{\text{tot}}(p)$. The corresponding activation volume $\Delta V^\ddagger$ is
computed by the same computational protocol used previously for the study of the effect of
pressure on a selection of pericyclic reactions, where reasonable agreement of the
computed activation volumes with experiment values were obtained.\textsuperscript{5} We highly
recommend interested readers refer to ref 5 for a more detailed and tutorial-like
description of the protocol. In this protocol, all the XP-PCM calculations are performed for
selected structures (reactants, transition state, product) along the gas phase intrinsic
reaction coordinates. The external medium transmitting the pressure is cyclohexane which
at standard thermodynamic condition has a relative dielectric constant $\varepsilon_0=2.0165$, and a
mean valence electron density $\rho=0.2004 \text{ eÅ}^{-3}$. The electronic energy $G_{\text{er}}$, and the pressure $P$
have been computed with the solute embedded in a van der Waals cavity. This cavity is
built up starting from the envelope of vdW spheres centered on the nuclei of the reactive
system and with scaled vdW radii. The standard vdW radii are multiplied by a scaling
factor in the range $f=1.2$–$0.95$. The smaller the value of $f$, the smaller the volume $V_c$ of the
cavity, and the higher the pressure. This range of values of the scaling factor yield values of
the pressure within the range $p = 1$–$10$ GPa. The Pauli repulsion barrier is located at the boundary of vdW cavity and the barrier height $Z_0$ is computed using $\eta=3$ as value of Pauli semi-empirical parameter. The cavitation energy $G_{cav}$ is computed exploiting the Scaled Particle Theory (SPT)$^{4,6}$ and using a vdW cavity with fixed scaling factor ($f=1.2$). The use of a fixed cavity for the calculation of $G_{cav}$ is due to reasons of physical consistency with the SPT method.
Disproportionation of *threo-4*

The retro-[4+2]-ene reaction of *threo-4* leads to cyclohexene and benzene (Figure S2). This reaction is calculated to have an enthalpic barrier of 39 kcal/mol, with respect to *threo-4*, at the ωB97X-D/def2-TZVP and CCSD(T)/def2-TZVP/ωB97X-D/def2-TZVP levels of theory.

**Figure S2.** 1 atm enthalpic profiles of the retro-[4+2]-ene reaction following the [6+4]-ene reaction, calculated at the ωB97X-D/def2-TZVP level of theory.
Supplementary reaction profiles to Figure 8

Comparison of the profiles in Figure S3 with the corresponding ones in Figure 8 in the maintext show that the profiles of endo and exo [4+2]-cycloadditions have similar behavior under pressure, so do the meso and rac stepwise additions.

Figure S3. Effective reaction profiles at different pressures and cavity volume profiles (vdW cavity with a scaling factor of 1.2 of the Bondi radii) of concerted exo-[4+2] cycloaddition, and the first step of the rac stepwise addition of cyclohexadiene dimerization, calculated by the XP-PCM method at the ωB97XD/def2-TZVP level.
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