EurJOC
European Journal of Organic Chemistry

A Journal of
ChemPubSoc Europe

Accepted Article

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To be cited as: *Eur. J. Org. Chem.* 10.1002/ejoc.201701212

Link to VoR: http://dx.doi.org/10.1002/ejoc.201701212

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FULL PAPER

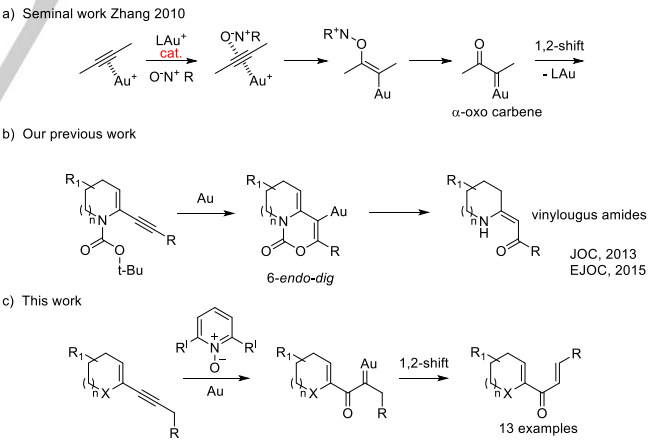
A gold(I)-catalyzed oxidative rearrangement of heterocycle-derived 1,3-enynes provides an efficient and selective route to divinyl ketones

Stefano Nejrotti,[a] Gabriele Prina Cerai,[a] Alberto Oppedisano,[a] Andrea Maranzana,[a] Ernesto G. Occhiato,[b] Dina Scarpi,[b] Annamaria Deagostino[a] and Cristina Prandi*[a]

Abstract: The gold-catalyzed oxidation of *N*-tosyl-protected 6-alkynyl-3,4-dihydro-2H-pyridines was studied in detail to obtain divinyl ketones in which one of the double bond is embedded in a heterocyclic framework. The best reaction conditions were then extended to different types of substrates to assess the scope of the reaction. DFT calculations were exploited to gain insight into the regio and chemoselectivity of the process too. The obtained divinyl ketones were then easily cyclized according to a Nazarov process and the bi- or polycyclic compounds used as scaffolds in the synthesis of analogues of plant hormones Strigolactones.

Introduction

Homogeneous gold catalysis is one of the most studied field in contemporary organic chemistry as it has dramatically brought to new advances in terms of synthetic opportunities.[1] Electrophilic gold complexes have been exhaustively employed as soft Lewis acids to activate alkynes toward nucleophilic attack. The gold intermediate derived from the *anti*-addition of the nucleophile can smoothly undergo proto-deauration in the presence of a protic nucleophile or to formal substitution when a suitable electrophile is employed. New avenues to this research field have been opened by the use of external oxidants to access α-oxo metal carbenes as useful intermediates for additional functionalization reaction. Since the first report by Zhang,[2] the gold-promoted addition of pyridine or quinoline *N*-oxides to an alkyne establishes an alkenylgold intermediate (Scheme 1, a). Subsequent heterolytic fragmentation of the weak O–N bond leads to the α-oxo gold carbene which directly undergoes transformations to functional products, thus giving access to an incredibly wide variety of compounds.[3] As a matter of fact the α-oxo gold carbene can undergo an extensive number of useful transformations including C-H insertions,[3h, 4] O-H and N-H insertions,[3g] cyclopropanations and ring expansion reactions.[5] The regioselective oxidation of internal, not symmetrical alkynes was also firstly reported by Zhang and coworkers.[6] Interestingly similar transformations were realized in the absence of gold, respectively catalyzed by $HBF_4 \cdot OEt_2$[7] and NIS.[8] Following our interest in the chemistry of heterocycle derived triflates and phosphates[9] as key intermediates in the synthesis of natural compounds[10] we have previously demonstrated that the gold(I)-catalyzed cyclization reaction of *N*-Boc-protected 6-alkynyl-3,4-dihydro-2*H*-pyridines affords synthetically useful vinylogous amides (Scheme 1, b*)*.[11] The reaction conditions have been optimized in order to enlarge the scope of the transformation and additional insights into the mechanism and the structural features that selectively favor a 6-*endo*-*dig* oxyauration process have been gained. The same selectivity was observed with *N*-Cbz-protected 2-alkynylpiperidines even if with lower yields, due to the concurrent presence of side reactions. Sedamine alkaloids have been easily obtained by this approach.[11a] Inspired by these results and by our general interest on the synthesis of heterocycle derived natural compounds, we envisioned that when the *N*-protecting group is a *p*-toluensulfonyl (Ts), the intramolecular path is prevented and an intermolecular reaction with an external oxidant can be featured. To this purpose we synthesized *N*-tosyl lactam- or lactone-derived enynes and used them as substrates in gold catalyzed oxidations in the presence of external oxidants (Scheme 1, c),[3a, 3j] as an alternative approach to functionalized heterocycles.



Scheme 1. Context and focus of the work

Results and Discussion

With *N*-Boc lactam-derived enynes, the gold catalyst activates the triple bond to the intramolecular attack of the nucleophilic oxygen of the Boc protecting group, however with *N*-tosyl-protected heterocycles the intramolecular cyclization is prevented. We were thus intrigued by the possibility of generating oxo-carbene starting from lactam or lactone derived

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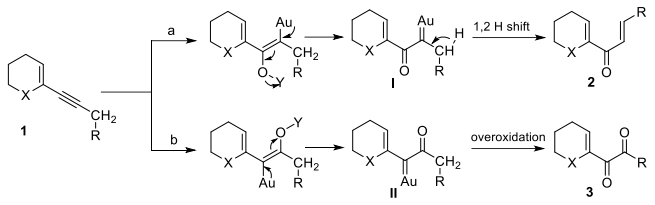
enynes. Ideally two different regioisomeric products could arise, depending on the preferential attack of the nucleophile either at C1 or C2 of the alkyne (path a and path b respectively, Scheme 2). Divinyl ketones **2** most likely derive from the regioselective single oxidation to α-oxo carbene **I** (Scheme 2) followed by a rapid 1,2-H shift to generate the α,β-unsaturated carbonyl compound.

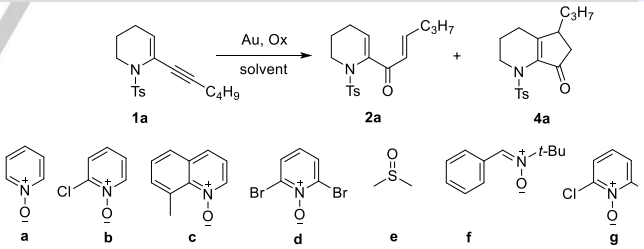


Scheme 2. Regioselectivity in gold catalysed oxidation.

Initial screening was performed on 6-hex-1-ynyl-1-(toluene-4-sulfonyl)-1,2,3,4-tetrahydropyridine **1a** with the addition of pyridine *N*-oxide **a** to the reaction mixture (Table 1, entry 1). The active gold(I) catalysts were generally prepared *in situ* by anion exchange between LAuX (where X = Cl, Br) and silver salts. We initially performed our screening in the presence of PPh_3AuCl and AgOTf in toluene as a solvent obtaining an acceptable conversion but a low yield of product **2**. We also tested the activity of a different gold complex (entry 2) changing from triflate anion to triflimidate. In both cases, the reactions were performed in the presence of 1.2 equivalents of MsOH as we envisaged that the deactivation of the gold catalyst could occur in the reaction media as a consequence of the strong coordination by the pyridine formed as side product in the reaction mixture. The addition of an acid in the reaction medium would trap the pyridine as pyridinium salt. With the use of the Gagosz catalyst[12] we were able to slightly improve the yield, however, unexpectedly but not surprisingly, the products obtained in this case were the divinyl ketone **2a** and a product deriving from the acid catalyzed Nazarov electrocyclization, the bicyclic ketone **4a**. Besides the addition of an acid, the drawback coming from the presence of pyridine in the reaction medium can be generally addressed by using less nucleophilic pyridines. An attempt was done in this sense, by switching to the less nucleophilic 2-chloropyridine *N*-oxide **b**, and indeed both the conversion and the isolated yield increased (Table 1, entry 3). Remarkably the reaction works nicely without acid added and also at rt the reaction yield was acceptable (entry 4). The addition of MsOH did not lead to substantial differences in the yield (entry 5). Acid free oxidation of asymmetric alkynes has already been obtained by Zhang and coworkers with high regioselectivities.[6] Remarkably under these conditions the formation of the Nazarov product was prevented. A higher loading of MsOH or the use of TFA did not push the ratio of the products towards the complete formation of the Nazarov product which remained a byproduct of the main product **2a** (entry 6). To exclude a possible catalytic role of silver itself we performed the reaction in the absence of gold catalyst thus confirming that in these conditions no oxidation product forms (entry 7). In a further attempt to prevent the decomposition of the catalyst by slowing down the rate of anion exchange and using copper salts instead of silver,[13] we used $Cu(MeCN)_4NTf_2$ as an additive (entries 8-10) but without any substantial improvement in yield. At this point, starting from the results obtained in entry 3 we decided to move our effort to optimize the selection of the oxidant. To this purpose we investigated a number of oxidants as 8-methylquinoline *N*-oxide **c** (entry 11), 2,6-dibromopyridine *N*-oxide **d** (entry 12), dimethylsulfoxide **e** (entry 13), (*Z*)-*N*-*tert*-butyl-1-phenylmethanimine oxide **f** (entry 14) and 2,6-dichloropyridine *N*-oxide **g** (entries 15-19). Best results were obtained with 2,6-dicholoropyridine **g** (entries 16-19).[14] In the presence of the Gagosz gold catalyst and under acidic conditions, the yield increased even thought a mixture of **2a** and **4a** were recovered. We then tested the same catalytic system/oxidant under neutral conditions (entry 16) and obtained pure **2a** in a 72% yield.

Once these conditions were established we decided to examine the activity of other gold catalysts. We first focused our attention on the bulky 2,4-di-*tert*-butylphenyl phosphite (entries 17) which was hypothesized to form a highly electrophilic Au(I) complex *in situ,*[15] and has been proved to be an optimal catalyst for the oxidation of conjugated alkynes.[6] Unfortunately, both at 110 °C and at rt, we were unable to recover any trace of the product. However, our results are in agreement with the ones reported by Goddard and Toste according which strongly π-acidic phosphite ligands are expected to increase carbocation-like vs. carbene reactivity by decreasing the gold-to-substrate back-donation.[16] Following this reasoning we then tested the *N*-heterocyclic ligand IPr (1,3-bis(2,6-diisopropylphenyl)imidazol-2-ylidene), whose strong σ-donating and only weakly π-acidic effects should drive the reactivity towards carbene. Also in this case we obtained a low yield of oxidation product (entry 18).

Table 1. Gold (I)-catalyzed reaction of enyne **1a**[a]. Optimization of reaction conditions.

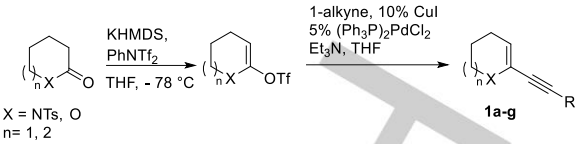


Entry	Add	Catalyst[a]	Ox	Yield (conv.)	Product
1	MsOH[b]	PPh_3AuOTf	**a**	10 (20)	**2a**
2	MsOH[c]	PPh_3AuNTf_2	**a**	28 (35)	**2a/4a**
3	-	PPh_3AuNTf_2	**b**	45 (80)	**2a**
4[d]	-	PPh_3AuNTf_2	**b**	40 (80)	**2a**
5	MsOH	PPh_3AuNTf_2	**b**	42 (100)	**2a**

6[d]	TFA	PPh_3AuNTf_2	**b**	-(35)	**2a/4a**
7[e]	-	-	**b**	-	-
8	-	$PPh_3AuCl/Cu(MeCN)_4NTf_2$	**b**	25 (50)	**2a**
9	MsOH	$PPh_3AuCl/Cu(MeCN)_4NTf_2$	**b**	12 (100)	**2a**
10[f]	-	$PPh_3AuCl/Cu(MeCN)_4NTf_2$	**b**	28 (55)	**2a**
11	-	PPh_3AuNTf_2	**c**	- (5)	-
12	-	PPh_3AuNTf_2	**d**	-(58)	**2a**
13	-	PPh_3AuNTf_2	**e**	5 (85)	**2a**
14	-	PPh_3AuNTf_2	**F**	- (10)	**2a**
15[d]	MsOH	PPh_3AuNTf_2	**g**	55 (100)	**2a/4a**
16	-	PPh_3AuNTf_2	**g**	72 (100)	**2a**
17	-	$[(2,4\text{-}^tBu_2PhO)_3P]AuNTf_2$	**g**	-	-
18[d]	-	$IPrAuNTf_2$	**g**	18 (78)-	-

[a] All the reactions were conducted with LAuCl (5 %) and AgX (5%) of catalyst loading in toluene at 110 °C if not differently indicated. [b] 1.2 equiv., DCE, rt. [c] 2.0 equiv., DCE, 70 °C. [d] rt. [e] 5.0 equiv of oxidant in the presence of only $AgNTf_2$. [f] 15% equiv. of catalyst.

The optimized gold-catalyzed oxidation conditions (entry 16) were then applied to a number of nitrogen and oxygen containing heterocyles to expand the scope of the reaction and investigate the tolerance to functional groups. Enynes **1a-o** were prepared by Sonogashira coupling as previously reported,[11] starting from the corresponding lactam or lactone derived triflates or phosphates (Scheme 3). Variability was introduced both on the heterocyclic ring in terms of heteroatom (oxygen or protected nitrogen) and size (6 or 7 member), and on the lateral alkyne chain.



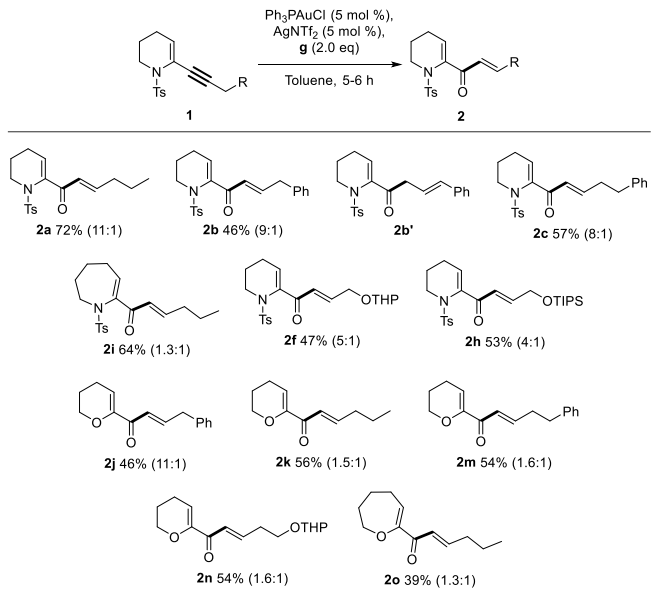
X = NTs, O
n= 1, 2

1a: X=NTs, n=1, R= $-(CH_2)_3CH_3$ (49%)
1b: X=NTs, n=1, R= $-(CH_2)_2Ph$ (51%)
1c: X=NTs, n=1, R= $-(CH_2)_3Ph$ (52%)
1d: X=NTs, n=1, R= $-CH(CH_2)_2$ (53%)
1e: X=NTs, n=1, R= $-(CH_2)_4OH$ (47%)
1f: X=NTs, n=1, R= $-(CH_2)_3OTHP$ (56%)
1g: X=NTs, n=1, R= -Ph (65%)
1h: X=NTs, n=1, R= $-(CH_2)_3OTIPS$ (66%)
1i: X=NTs, n=2, R= $-(CH_2)_3CH_3$ (84%)
1j: X=O, n=1, R= $-(CH_2)_2Ph$ (59%)
1k: X=O, n=1, R= $-(CH_2)_3CH_3$ (71%)
1l: X=O, n=1, R= $-(CH_2)_2OTIPS$ (57%)
1m X=O, n=1, R= $-(CH_2)_3Ph$ (76%)
1n: X=O, n=1, R= $-(CH_2)_3OTHP$ (88%)
1o: X=O, n=2, R= $-(CH_2)_3CH_3$ (84%)

Scheme 3. Synthesis of compounds **1a-o.** KHMDS = potassium hexamethyldisilazide; TIPS = triisopropylsilyl; THP = tetrahydropyranyl. Yields in brackets refer to isolated products (see SI).

Enynes **1a-o** were then oxidized in the presence of PPh_3AuNTf_2 as a catalyst and 2,6-dichloropyridine *N*-oxide as an oxidant. All the reactions were performed in the absence of acid in the reaction medium, consequently no Nazarov product was detected and divinyl ketones **2** were recovered as the only products (Table 2). In all cases stereochemistry at the double bond of the side chain was found to be *E*. In case of compounds **2b** and **2j**, isomerization of the double bond to form **2b'** and **2j'** respectively has been observed.[17] This migration, whose driving force arises from the conjugation with the aromatic ring, was prevented when the reaction was performed at room temperature: in this case only the product **2b** and **2j** were formed. When instead the reaction was carried out with substrate **1e** (from 5-hexyn-1-ol), the gold-catalysed oxidation did not occur at all as we recovered the unaltered substrate after 4 h in boiling toluene. The reason for the unsuitability of a δ-hydroxyl group as in substrates **1e**, is still unclear. We have already reported the unreactivity of the same substrate as *N*-Boc protected in gold catalysis.[11a] We put forward the hypothesis that the side chain OH could compete with the pyridine *N*-oxide as a nucleophile onto the gold activated triple bond thus preventing the intermolecular oxidation. In fact, when the OH group was protected either as THP ether (**1f** and **1n**) or as TIPS (**1h**), the whole process took place smoothly, and divinyl ketones **2f**, **2n** and **2h** were obtained in good yields, after chromatography. In any case, the above results suggest that protection of the OH group in the side chain is either necessary or preferable.

Table 2. Substrate scope of the transformation.[a)]

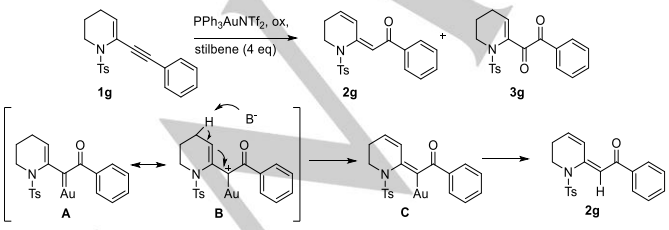


[a)] Isolated yields of desired product. Alkyne (1.0 equiv.), Oxidant **g** (2.0 equiv.); Ph_3PAuCl (5%), $AgNTf_2$ (5%). Regioselectivity defined as the ratio **2**:**3** (desired product : diketone) is shown in parenthesis.

Unfortunately, when cyclopropyl enyne **1d** was used as substrate for the gold catalyzed oxidation, only degradation by-products were recovered.

As shown in Scheme 2, in principle the attack of the nucleophilic oxidant can take place either at the C1 or C2 sp carbons leading to divinyl ketones **2** or alternatively to diketones **3** as a result of overoxidation. According to path a, the regioisomeric attack of the oxidant to C1 of the alkyne leads to the gold carbene intermediate **A**. With the aim of bringing evidence to the involvement of a gold carbene intermediate in this process we synthesized enyne **1g** 6-(phenylethynyl)-1-tosyl-1,2,3,4-tetrahydropyridine and used it in the gold catalyzed oxidation (Scheme 4). When we performed the reaction under the gold catalyzed optimized conditions in the presence of *cis*-stilbene as carbene trap, we did not recover any cyclopropanation product as expected but only compound **2g** alongside with the diketone **3g** in 4:1 ratio**.** For this substrate, we envisaged that the competitive C-H insertion is precluded so that the reactive carbene **A**, if formed, can undergo a different destiny.

Scheme 4. 1g (1.0 equiv.), 2,6-dichloropyridine *N*-oxide (2.0 equiv.); catalyst

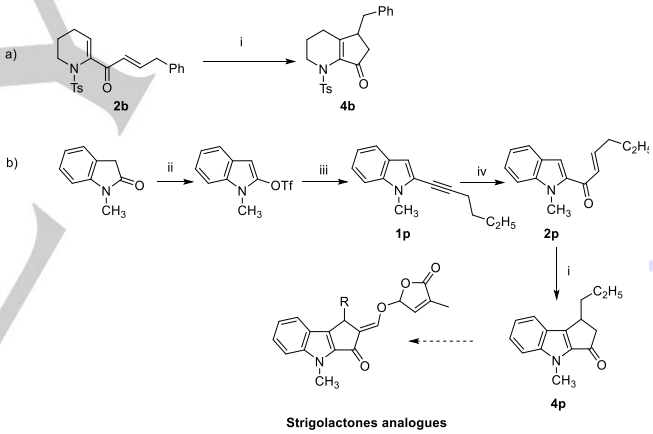


$Ph_3PAuNTf_2$ (5 mol %); *cis*-stilbene (4.0 equiv), toluene, rt.

Compound **2g** can then arise from a deprotonative Grob-type fragmentation of **B** (Scheme 4) followed by fast deprotoauration of **C**, the driving force of the process being the formation of a highly conjugated compound.[8]

Divinyl ketones in which one of the double bond is embedded into a heterocycle framework are highly versatile and useful compounds. We have extensively made use of these intermediates to construct skeletons of natural compounds.[9] One of the most widespread synthetic transformation based on the electrocyclization of divinyl ketones is the Nazarov reaction. As expected, compounds **2** obtained from the gold catalyzed oxidation are feasible substrates for the Nazarov electrocyclization and can be straightforwardly converted into cyclopentafused systems (Scheme 5, a). As a further application of the proposed methodology we applied the synthetic sequence to the synthesis of a class of plant hormones and their analogues, known as Strigolactones. Strigolactones are of cutting-edge interest for their well-known effects on plants[10d, 18] and as antitumoral agents.[19] We then envisage a new synthetic approach to indolyl analogues of Strigolactones exploiting the herein proposed sequence, gold catalysed oxidation of enynes followed by Nazarov cyclization. This sequence successfully allows the introduction of suitable substituents in the β-position of the cyclopentaindolynone nucleus (Scheme 5, b).

Scheme 5. Gold catalyzed oxidation followed by Nazarov cyclization applied to the synthesis of Strigolactones analogues. i) TFA, 0 °C to rt. ii) KHMDS, $PhNTf_2$,



THF, -78 °C; iii) 1-hexyne, $(Ph_3P)_2PdCl_2$, CuI, THF/Et_3N; iv) Ph_3PAuCl, $AgNTf_2$, 2,6-dichloropyridine *N*-oxide, toluene, rt.

We finally carefully investigated the regioselectivity and chemoselectivity of the gold catalyzed oxidation reaction on lactam derived enynes 1. For all the substrates from high to good regioselectivities in favour of compounds 2 were obtained. Generally speaking, high regioselectivities were obtained with six-membered lactam derived enynes. Caprolactam and lactone derived enynes showed a higher amount of overoxidation products 3. As effectively discussed by Zhang in his paper on the oxidation of asymmetric alkynes,[6] both electronic and resonance effects are involved in determining the regioselectivity of the reaction. To get further insight into the reasons for the different regioselectivities, and to ascertain whether the electronic or steric effects were affecting the regiochemistry of the reaction additional, DFT calculations were carried out with the Gaussian 09 suite of programs (see Computational Methods section).

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Compounds 1a and 1i were selected as model substrates for the oxidation reaction, as examples of the possible combinations of different size rings and substituted/unsubstituted alkynes. Triphenylphosphine gold(I) cation was used as the reaction catalyst, and the study focused on the nucleophile-gold addition step, which is the regioselectivity-determining step. We have performed Natural Bond Orbital (NBO) analysis[20] to estimate the charge distributions on the two intermediates derived from the coordination of the gold electrophilic complex to the triple bond.

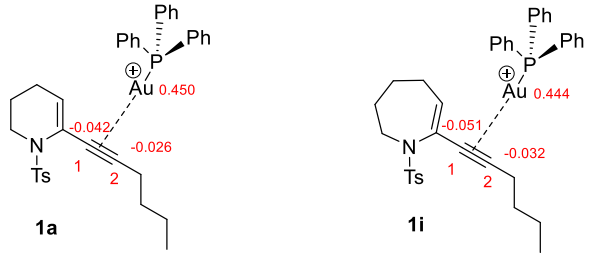

Figure 1. NBO charges for the adducts **1a**-PPh_3Au (left) and **1i**-PPh_3Au (right)

In the **1a**-PPh_3Au adduct, the charges on the two carbons involved in the triple bond are almost identical (-0.042 vs -0.026): such a modest difference is unable to account for the observed regioselectivity (see Scheme 6). In the **1i**-PPh_3Au intermediate, the charge difference on the two carbons is slightly larger but not enough to convincingly interpret the observed product distributions: the regioselectivity has probably other origin. This is in agreement with our previous results on Boc and Cbz protected lactam derived enynes.[21] The transition structures (TS) for **1a**-PPh_3Au and **1i**-PPh_3Au oxidations, which entail the oxygen transfer from 2,6-dichloropyridine *N*-Oxide to **1a**-PPh_3Au and **1i**-PPh_3Au, could help to clarify the issue. First of all, the four TS (two for **1a**, depending on which carbon atom is attacked, and two for **1i**) are geometrically very similar and very late from a geometrical point of view (Figure 2 and Supporting Info).

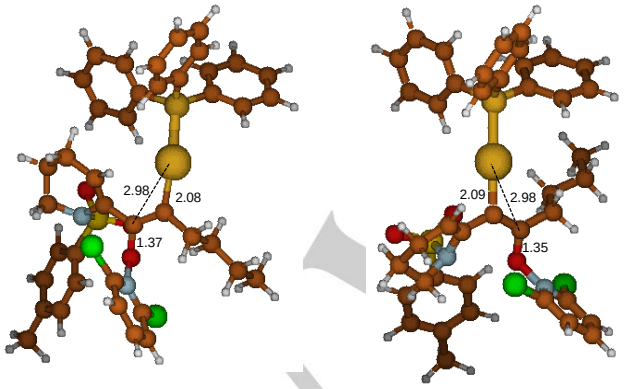

Figure 2. TS 1a-PPh_3Au + 2,6-dichloropyridine A and TS 1a-PPh_3Au + 2,6-dichloropyridine B.

Focusing the attention on the triple bond, the gold atom is now bonded to one of the two carbons only (Au-C=2.08-2.09 Å), whereas the other Au-C distance is very large (2.95-2.98 Å). The C-O (O of the pyridine *N*-Oxide) is quite short C-O = 1.35-1.37 Å. The lateness of these TSs suggests that the charge distributions in the **1a**-PPh_3Au and **1i**-PPh_3Au intermediates are not useful to predict the regioselectivity, because the oxidative steps occur at significantly different geometries. As concern the kinetics, we are aware that the quantitative reproduction of the product distributions (11:1 for **1a** and 1.3:1 for **1i**), which correspond to very small energy differences, is beyond the capabilities of DFT methods. More demanding computations, such as coupled cluster, would be needed, but these methods are unfeasible on such a large molecule. Nevertheless, the DFT results could give some interesting indications. For TS **1a**, the O addition to C2 of the hex-1-yne group is lower than the addition to C1 by 1.85 kcal mol^{-1} in term of Free Energy and 2.2 kcal mol^{-1} in term of Enthalpy. These results are in disagreement with the observed regioselectivity. For TS **1i**, the behavior is opposite and the O addition to C1 is lower than the addition to C2 by 0.73 kcal mol^{-1} in terms of Free Energy and 1.48 kcal mol^{-1} in terms of Enthalpy. In this case, the results are in agreement with the experimental products. However, more interesting than the raw energy values is the comparison between Enthalpies and Free Energies (therefore the entropies) effects: electronic (enthalpy) and steric effects (entropy) both contribute to the overall regioselectivity. The enthalpy promotes the oxidation of one of the carbon atoms. On the other hand, the Free Energy decreases, in this case, the selectivity and it could even become the dominant factor: this effect should be more evident raising the temperature. These data suggest the steric effect could play an important role on the regioselectivity. However, more accurate calculations would be required to confirm this hypothesis.

Conclusions

In conclusion, in this paper we have investigated the feasibility of the gold catalyzed oxidation on lactam or lactone derived enynes. Considering that these intermediates are usually accessed through metal catalyzed decomposition of diazo compounds, the utility of this approach is even more interesting.
The reaction takes place with good yields and affords divinyl ketones with complete *E*-selectivity under very mild conditions (room temperature, no additives, neutral pH, and mild oxidants). The reaction conditions are compatible with a wide range of functional groups. This synthetic transformation provides access to divinyl ketones in which one of the double bonds is embedded in a heterocycle, these structures are widely represented in natural products and additionally can be easily converted into polycyclic compounds under feasible electrocyclic Nazarov reaction.

Experimental Section

Computational Methods: Stationary points on the energy hypersurface were determined by gradient procedures[22] within the Density Functional Theory (DFT),[23] and making use of the M06 functional.[24] The polarized split-valence shell 6-311G(d)[25] were used in the DFT-PCM optimizations (with PCM included); the effective core potential SDD[26] was used for Au

atom only. The nature of the critical points was checked by vibrational analysis. The M06 functional was expected to perform acceptably on the basis of literature studies.[27] Since the experimental part of the study was carried out in the liquid phase, solvent (toluene) was simulated using the polarized continuum method, within the SMD[28] and IEF-PCM[29] schemes. According to the experimental section, the enthalpies and the Gibbs free energies reported in the text, were estimated at T = 323 K. Quantum mechanical calculations were carried out by using the GAUSSIAN09 system of programs Geometries and energetics of all the species are reported in the Supporting Information.[30]

General Information: Flasks and all equipment used for the generation and reaction of moisture-sensitive compounds were dried by electric heat gun under nitrogen. Anhydrous THF was obtained by distillation over $LiAlH_4$, followed by distillation over Na-benzophenone; anhydrous CH_2Cl_2 was obtained by distillation over CaH_2; Et_3N was distilled over CaH_2. All other commercially available reagents were used without further purification. Flash column chromatography was performed over silica gel (40-63 µm, 230-400 mesh); R_f values refer to TLC carried out on silica gel plates. ^1H NMR and ^{13}C NMR spectra were recorded on a Bruker Avance 200 or on a Jeol ECZR600, in $CDCl_3$, using residual solvent peak as an internal standard ($CHCl_3$, ^1H: 7.26 ppm, ^{13}C: 77.16 ppm; CH_2Cl_2, ^1H: 5.30 ppm). Multiplicity is reported as follows: s (singlet), d (doublet), t (triplet), q (quartet), sext (sextet), m (multiplet). GC-MS spectra were recorded at an ionizing voltage of 70 eV. ESI-MS spectra were carried out by direct inlet of a 20 ppm solution in CH_3OH on a LCQ FleetTM Ion Trap LC/MS system (Thermo Fisher Scientific) with an electrospray ionization (ESI) interface in the positive mode. Microanalysis were carried out on an elemental analyser. Infrared spectra were acquired in the ATR configuration. For the synthesis of the *N*-tosyl protected lactam, triflate and protected alcohol intermediates, see the Supporting Information.

General procedure for Sonogashira coupling: In a reaction tube under nitrogen atmosphere, $(Ph_3P)_2PdCl_2$ (0.05 eq) and CuI (0.1 eq) were added as solids. A solution of crude triflate or phosphate (1.0 eq, 0.13 M) in anhydrous 3:1 Et_3N/THF was added and the mixture was degassed for 15 min, then the alkyne (1.2 eq) was added and the mixture was degassed for another 15 min. The mixture was stirred under nitrogen atmosphere at room temperature until full consumption of the starting material (TLC monitoring, usually 0.5-1 h). A saturated NH_4Cl solution (10 ml) was added and the mixture was extracted with CH_2Cl_2 (3x15 ml); the combined organic layers were dried over Na_2SO_4, filtered and the solvent was removed under reduced pressure. The crude enyne was purified by flash chromatography (eluent containing 0.1% Et_3N) and stored at 4 °C as a 0.1 M solution in CH_2Cl_2 until use.

6-(hex-1-yn-1-yl)-1-tosyl-1,2,3,4-tetrahydropyridine (1a): Yellow oil (49%, 2-step). R_f 0.48 (9:1 PE/EtOAc). ^1H NMR (200 MHz) δ (ppm): 7.77 (d, 2H, *J* = 8.3 Hz), 7.28 (d, 2H, *J* = 8.0 Hz), 5.53 (t, 1H, *J* = 4.0 Hz), 3.71-3.64 (m, 2H), 2.42 (s, 3H), 2.25 (t, 2H, *J* = 6.7 Hz), 2.10-2.00 (m, 2H), 1.72-1.58 (m, 2H), 1.52-1.31 (m, 4H), 0.90 (t, 3H, *J* = 7.0 Hz). ^{13}C NMR (50.2 MHz) δ (ppm): 143.3 (Cq), 137.8 (Cq), 129.4 (CH), 127.5 (CH), 122.1 (CH), 121.2 (Cq), 111.4 (Cq), 91.3 (Cq), 46.1 (CH_2), 30.5 (CH_2), 30.5 (CH_2), 23.3 (CH_2), 22.1 (CH_2), 21.6 (CH_3), 21.4 (CH_2), 19.2 (CH_2), 13.7 (CH_3). GC-MS *m/z* (%) = 317 $[M]^+$ (100), 162 (68), 91 (43), 55 (78).

6-(4-phenylbut-1-yn-1-yl)-1-tosyl-1,2,3,4-tetrahydropyridine (1b): Yellow oil (51%, 2-step). R_f 0.25 (9:1 PE/EtOAc). ^1H NMR (200 MHz) δ (ppm): 7.76 (d, 2H, *J* = 8.3 Hz), 7.38-7.14 (m, 7H), 5.55 (t, 1H, *J* = 4.1 Hz), 3.74-3.65 (m, 2H), 2.83 (t, 2H, *J* = 7.5 Hz), 2.57 (t, 2H, *J* = 7.5 Hz), 2.43 (s, 3H), 2.12-2.00 (m, 2H), 1.71-1.57 (m, 2H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.3 (Cq), 140.7 (Cq), 137.7 (Cq), 129.4 (CH), 128.5 (CH), 128.4 (CH), 127.5 (CH), 126.3 (CH), 122.5 (CH), 121.0 (Cq), 90.3 (Cq), 77.2 (Cq), 46.1 (CH_2), 34.7 (CH_2), 23.2 (CH_2), 21.6 (CH_3), 21.6 (CH_2), 21.2 (CH_2). GC-MS *m/z* (%) = 365 $[M]^+$ (83), 210 (60), 91 (100), 79 (39).

6-(5-phenylpent-1-yn-1-yl)-1-tosyl-1,2,3,4-tetrahydropyridine (1c): Dark yellow oil (52%, 2-step). R_f 0.25 (9:1 PE/EtOAc). ^1H NMR (200 MHz) δ (ppm): 7.79 (d, 2H, *J* = 8.3 Hz), 7.37-7.15 (m, 7H), 5.58 (t, 1H, *J* = 4.1 Hz), 3.74-3.65 (m, 2H), 2.79-2.67 (m, 2H), 2.40 (s, 3H), 2.29 (t, 2H, *J* = 7.0 Hz), 2.13-2.02 (m, 2H), 1.91-1.74 (m, 2H), 1.72-1.58 (m, 2H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.3 (Cq), 141.7 (Cq), 137.7 (Cq), 129.5 (CH), 128.6 (CH), 128.4 (CH), 127.4 (CH), 125.9 (CH), 122.3 (CH), 121.1 (Cq), 90.7 (Cq), 77.1 (Cq), 46.1 (CH_2), 34.9 (CH_2), 30.0 (CH_2), 23.3 (CH_2), 21.6 (CH_3), 21.3 (CH_2), 18.9 (CH_2). GC-MS *m/z* (%) = 379 $[M]^+$ (62), 224 (83), 196 (30), 91 (100), 55 (90).

6-(cyclopropylethynyl)-1-tosyl-1,2,3,4-tetrahydropyridine (1d): Dark yellow oil (53%, 2-step). R_f 0.33 (9:1 PE/EtOAc). ^1H NMR (200 MHz) δ (ppm): 7.76 (d, 2H, *J* = 8.3 Hz), 7.29 (d, 2H, *J* = 8.0 Hz), 5.51 (t, 1H, *J* = 4.1 Hz), 3.71-3.62 (m, 2H), 2.42 (s, 3H), 2.10-1.98 (m, 2H), 1.71-1.57 (m, 2H), 1.38-1.22 (m, 1H), 0.84-0.73 (m, 2H), 0.72-0.62 (m, 2H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.3 (Cq), 137.8 (Cq), 129.4 (CH), 127.5 (CH), 122.1 (CH), 121.0 (Cq), 94.1 (Cq), 71.7 (Cq), 46.0 (CH_2), 23.3 (CH_2), 21.6 (CH_3), 21.4 (CH_2), 8.3 (CH_2), 0.1 (CH). GC-MS *m/z* (%) = 301 $[M]^+$ (100), 146 (44), 91 (41), 55 (68)..

6-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)hex-5-yn-1-ol (1e): Dark yellow oil (47%, 2-step). R_f 0.15 (7:3 PE/EtOAc + 0.1% Et_3N). ^1H NMR (200 MHz) δ (ppm): 7.76 (d, 2H, *J* = 8.3 Hz), 7.29 (d, 2H, *J* = 8.0 Hz), 5.55 (t, 1H, *J* = 4.1 Hz), 3.70-3.61 (m, 4H), 2.42 (s, 3H), 2.32 (t, 2H, *J* = 6.4 Hz), 2.09-1.98 (m, 2H), 1.75-1.52 (m, 6H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.4 (Cq), 137.5 (Cq), 129.5 (CH), 127.5 (CH), 122.5 (CH), 121.1 (Cq), 90.8 (Cq), 77.1 (Cq), 62.4 (CH_2), 46.1 (CH_2), 31.8 (CH_2), 24.6 (CH_2), 23.2 (CH_2), 21.6 (CH_3), 21.1 (CH_2), 19.2 (CH_2). GC-MS *m/z* (%) = 333 $[M]^+$ (4), 178 (100), 91 (75), 55 (97).

6-(5-((tetrahydro-2H-pyran-2-yl)oxy)pent-1-yn-1-yl)-1-tosyl-1,2,3,4-tetrahydropyridine (1f): Yellow oil (66%, 2-step). R_f 0.48 (8:2 PE/EtOAc) ^1H NMR (200 MHz) δ (ppm): 7.74 (d, 2H, *J* = 8.2 Hz), 7.26 (d, 2H, *J* = 8.2 Hz), 5.51 (t, 1H, *J* = 4.0 Hz), 4.60-4.54 (m, 1H), 3.90-3.71 (m, 2H), 3.68-3.61 (m, 2H), 3.54-3.39 (m, 2H), 2.40-2.32 (m, 2H), 2.07-1.97 (m, 2H), 1.83-1.65 (m, 4H), 1.65-1.45 (m, 6H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.3 (Cq), 137.7 (Cq), 129.5 (CH), 127.5 (CH), 122.3 (CH), 121.1 (Cq), 98.9 (CH), 90.5 (Cq), 76.8 (Cq), 66.1 (CH_2), 62.3 (CH_2), 46.1 (CH_2), 30.8 (CH_2), 28.6 (CH_2), 25.5 (CH_2), 23.2 (CH_2), 21.6 (CH_3), 21.3 (CH_2), 19.6 (CH_2), 16.4 (CH_2). ESI-MS *m/z* (%) = 829 $[2M+Na]^+$ (8), 426 $[M+Na]^+$ (100). MS/MS of 426 *m/z* (%): 426 (8), 271 (100).

6-(phenylethynyl)-1-tosyl-1,2,3,4-tetrahydropyridine (1g): Dark yellow oil (52%, 2-step). R_f 0.34 (9:1 PE/EtOAc). ^1H NMR (200 MHz) δ (ppm): 7.82 (d, 2H, *J* = 8.3 Hz), 7.45-7.38 (m, 2H), 7.34-7.23 (m, 5H), 5.74 (t, 1H, *J* = 4.1 Hz), 3.78-3.71 (m, 2H), 2.40 (s, 3H), 2.18-2.09 (m, 2H), 1.76-1.63 (m, 2H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.5 (Cq), 137.4 (Cq), 131.5 (CH), 129.6 (CH), 128.5 (CH), 128.3 (CH), 127.5 (CH), 123.6 (CH), 122.9 (Cq), 121.0 (Cq), 89.9 (Cq), 85.6 (Cq), 46.2 (CH_2), 23.4 (CH_2), 21.6 (CH_3), 21.2 (CH_2). GC-MS *m/z* (%) = 337 $[M]^+$ (100), 182 (64), 128 (58), 91 (36).

1-tosyl-6-(5-((triisopropylsilyl)oxy)pent-1-yn-1-yl)-1,2,3,4-tetrahydropyridine (1h): Yellow oil (66%, 2-step). R_f 0.51 (9:1 PE/EtOAc) ^1H NMR (200 MHz) δ (ppm): 7.77 (d, 2H, *J* = 8.3 Hz), 7.28 (d, 2H, *J* = 8.1 Hz), 5.53 (t, 1H, *J* = 4.0 Hz), 3.75 (t, 2H, *J* = 6.0 Hz), 3.71-3.64 (m, 2H), 2.47-2.33 (m, 5H), 2.11-1.99 (m, 2H), 1.80-1.57 (m, 4H), 1.12-1.00 (m, 21H). ^{13}C NMR (50.2 MHz) δ (ppm): 143.3 (Cq), 137.8 (Cq), 129.4 (CH), 127.5 (CH), 122.1 (CH), 121.2 (Cq), 90.9 (Cq), 76.6 (Cq), 62.1 (CH_2), 46.1 (CH_2), 31.7 (CH_2), 23.2 (CH_2), 21.6 (CH_3), 21.4 (CH_2), 18.1 (CH_3), 16.0

(CH_2), 12.0 (CH_2). ESI-MS *m/z* (%) = 973 $[2M+Na]^+$ (5), 498 $[M+Na]^+$ (100), 476 $[M+H]^+$ (24).

7-(hex-1-yn-1-yl)-1-tosyl-2,3,4,5-tetrahydro-1H-azepine (1i): In this case, the reaction was performed at 55 °C instead of room temperature. Dark yellow oil (84%). R_f 0.38 (9:1 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 7.83 (d, 2H, *J* = 8.3 Hz), 7.25 (d, 2H, *J* = 8.2 Hz), 6.03 (t, 1H, *J* = 6.9 Hz), 3.41-3.32 (m, 2H), 2.40 (s, 3H), 2.28-2.10 (m, 4H), 1.92-1.78 (m, 2H), 1.55-1.26 (m, 6H), 0.86 (t, 3H, *J* = 7.1 Hz). ^{13}C NMR (50.2 MHz) δ (ppm): 143.0 (Cq), 138.3 (Cq), 135.5 (CH), 129.2 (CH), 127.6 (CH), 125.8 (Cq), 90.6 (Cq), 77.2 (Cq), 50.1 (CH_2), 31.1 (CH_2), 30.5 (CH_2), 27.4 (CH_2), 23.8 (CH_2), 22.1 (CH_2), 21.6 (CH_3), 19.1 (CH_2), 13.7 (CH_3). GC-MS *m/z* (%) = 331 $[M]^+$ (17), 176 (100), 91 (16).

6-(4-phenylbut-1-yn-1-yl)-3,4-dihydro-2H-pyran (1j): Pale yellow oil (73%, 2-step). R_f 0.50 (95:5 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 7.30-7.10 (m, 5H), 5.04 (t, 1H, *J* = 4.1 Hz), 4.00-3.92 (m, 2H), 2.80 (t, 2H, *J* = 7.6 Hz), 2.53 (t, 2H, *J* = 7.7 Hz), 2.07-1.96 (m, 2H), 1.83-1.69 (m, 2H). ^{13}C NMR (50.2 MHz) δ (ppm): 140.7 (Cq), 137.5 (Cq), 128.5 (CH), 126.4 (CH), 107.4 (CH), 87.6 (Cq), 77.0 (Cq), 66.5 (CH_2), 35.0 (CH_2), 21.9 (CH_2), 21.4 (CH_2), 20.9 (CH_2). GC-MS *m/z* (%) = 212 $[M]^+$ (64), 91 (100)..

6-(hex-1-yn-1-yl)-3,4-dihydro-2H-pyran (1k): Pale yellow oil (74%, 2-step). R_f 0.33 (98:2 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 5.09 (t, 1H, *J* = 4.1 Hz), 4.05-3.97 (m, 2H), 2.30 (t, 2H, *J* = 6.8 Hz), 2.12-2.01 (m, 2H), 1.88-1.74 (m, 2H), 1.60-1.34 (m, 4H), 0.89 (t, 3H, *J* = 7.1 Hz). ^{13}C NMR (50.2 MHz) δ (ppm): 137.6 (Cq), 107.1 (CH), 88.6 (Cq), 76.4 (Cq), 66.6 (CH_2), 30.6 (CH_2), 22.1 (CH_2), 22.0 (CH_2), 20.9 (CH_2), 18.9 (CH_2), 13.7 (CH_3). GC-MS *m/z* (%) = 164 $[M]^+$ (100), 109 (49), 79 (39).

((4-(3,4-dihydro-2H-pyran-6-yl)but-3-yn-1-yl)oxy)triisopropylsilane (1l): Pale yellow oil (57%, 2-step). R_f 0.50 (99:1 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 5.11 (t, 1H, *J* = 4.0 Hz), 4.05-3.97 (m, 2H), 3.81 (t, 2H, *J* = 7.6 Hz), 2.55 (t, 2H, *J* = 7.6 Hz), 2.12-1.01 (m, 2H), 1.88-1.74 (m, 2H), 1.10-1.02 (m, 21H). ^{13}C NMR (50.2 MHz) δ (ppm): 137.4 (Cq), 107.6 (CH), 85.1 (Cq), 77.5 (Cq), 66.6 (CH_2), 61.9 (CH_2), 23.6 (CH_2), 22.0 (CH_2), 20.9 (CH_2), 18.1 (CH_3), 12.1 (CH).

6-(5-phenylpent-1-yn-1-yl)-3,4-dihydro-2H-pyran (1m): Pale yellow oil (76%, 2-step). R_f 0.38 (98:2 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 7.35-7.14 (m, 5H), 5.13 (t, 1H, *J* = 4.0 Hz), 4.07-4.00 (m, 2H), 2.73 (t, 2H, *J* = 7.6 Hz), 2.33 (t, 2H, *J* = 7.1 Hz), 2.14-2.04 (m, 2H), 1.95-1.76 (m, 4H). ^{13}C NMR (50.2 MHz) δ (ppm): 141.6 (Cq), 137.5 (Cq), 128.7 (CH), 128.5 (CH), 126.0 (CH), 107.3 (CH), 88.0 (Cq), 77.0 (Cq), 66.6 (CH_2), 34.9 (CH_2), 30.1 (CH_2), 22.0 (CH_2), 20.9 (CH_2), 18.6 (CH_2). GC-MS *m/z* (%) = 226 $[M]^+$ (100), 91 (75), 79 (35).

6-(5-((tetrahydro-2H-pyran-2-yl)oxy)pent-1-yn-1-yl)-3,4-dihydro-2H-pyran (1n): Pale yellow oil (88%, 2-step). R_f 0.52 (9:1 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 5.08 (t, 1H, *J* = 4.0 Hz), 4.61-4.54 (m, 1H), 4.03-3.96 (m, 2H), 3.54-3.39 (m, 2H), 2.41 (t, 2H, *J* = 7.1 Hz), 2.11-2.00 (m, 2H), 1.88-1.67 (m, 6H), 1.64-1.44 (m, 4H). ^{13}C NMR (50.2 MHz) δ (ppm): 137.5 (Cq), 107.3 (CH), 98.9 (CH), 87.8 (Cq), 76.6 (Cq), 66.5 (CH_2), 66.0 (CH_2), 30.8 (CH_2), 28.8 (CH_2), 25.6 (CH_2), 21.9 (CH_2), 20.9 (CH_2), 19.6 (CH_2), 16.1 (CH_2). GC-MS *m/z* (%) = 250 $[M]^+$ (3), 166 (100), 165 (56), 85 (76).

7-(hex-1-yn-1-yl)-2,3,4,5-tetrahydrooxepine (1o): Pale yellow oil (84%, 2-step). R_f 0.40 (98:2 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 5.30 (t, 1H, *J* = 6.1 Hz), 3.95-3.87 (m, 2H), 2.25 (t, 2H, *J* = 6.8 Hz), 2.17-2.06 (m, 2H), 1.86-1.72 (m, 2H), 1.64-1.51 (m, 2H), 1.50-1.28 (m, 4H), 0.85 (t, 3H, *J* = 7.0 Hz). ^{13}C NMR (50.2 MHz) δ (ppm): 142.8 (Cq), 117.2 (CH), 87.9 (Cq), 77.7 (CH), 72.6 (CH_2), 31.6 (CH_2), 30.6 (CH_2), 26.7 (CH_2), 25.3 (CH_2), 22.0 (CH_2), 18.8 (CH_2), 13.6 (CH_3). GC-MS *m/z* (%) = 178 $[M]^+$ (100), 163 (92), 109 (34), 91 (36), 79 (52).

2-(hex-1-yn-1-yl)-1-methyl-1H-indole (1p): Pale yellow oil (53%, 2-step). R_f 0.51 (99:1 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 7.61 (d, 1H, *J* = 7.8 Hz), 7.29-7.25 (m, 2H), 7.20-7.10 (m, 1H), 6.73 (d, 1H, *J* = 1.6 Hz), 3.78 (s, 3H), 2.55 (t, 2H, *J* = 6.8 Hz), 1.76-1.47 (m, 4H), 1.03 (t, 3H, *J* = 7.1 Hz). ^{13}C NMR (50.2 MHz) δ (ppm): 137.0 (Cq), 127.4 (Cq), 123.0 (Cq), 122.5 (CH), 120.7 (CH), 119.9 (CH), 109.3 (CH), 106.1 (CH), 96.6 (Cq), 72.4 (Cq), 30.8 (CH_2), 30.5 (CH_3), 22.2 (CH_2), 19.5 (CH_2), 13.7 (CH_3). GC-MS *m/z* (%) = 211 $[M]^+$ (100), 196 (17), 182 (20), 168 (81).

General procedure for gold-catalysed oxidation: In a reaction tube under nitrogen atmosphere, Ph_3PAuCl (0.05 eq) and $AgNTf_2$ (0.05 eq) were added as solids, and solubilized in 1-1.5 ml of anhydrous toluene. 2,6-dicloropyridine *N*-oxide (2.0 eq) was added as a solid, followed by the addition of a 0.2 M solution of the enyne (1.0 eq, 0.10-0.50 mmol) in anhydrous toluene. The reaction was monitored by TLC (usually reaction time was 5-6 h). Then, the reaction mixture was filtered through a celite pad using CH_2Cl_2 and the solvent was removed under reduced pressure to afford crude divinyl ketone, which was purified by flash chromatography (eluent containing 0.1% Et_3N).

(*E*)-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)hex-2-en-1-one (2a):[31] Pale yellow oil (72%). R_f 0.35 (8:2 PE/EtOAc). ^{1}H NMR (200 MHz, $CDCl_3$) δ (ppm): 7.75 (d, 2H, *J* = 8.3 Hz), 7.31 (d, 2H, *J* = 8.2 Hz), 7.00 (dt, 1H, *J* = 15.5 Hz, 6.9 Hz), 6.56 (dt, 1H, *J* = 15.6 Hz, 1.4 Hz), 6.08 (t, 1H, *J* = 3.9 Hz), 3.52-3.44 (m, 2H), 2.43 (s, 3H), 2.31-2.18 (m, 2H), 2.12-2.02 (m, 2H), 1.53 (sext, 2H, *J* = 7.4 Hz), 1.40-1.25 (m, 2H), 0.96 (t, 3H, *J* =7.4 Hz). GC-MS *m/z* (%) = 333 $[M]^+$ (9), 290 (68), 226 (59), 178 (100), 135 (46), 91 (62), 55 (52).

(*E*)-4-phenyl-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)but-2-en-1-one (2b) and **(*E*)-4-phenyl-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)but-3-en-1-one (2b'):** Pale yellow oil (46%). R_f 0.33 (8:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.74 (d, 2H, **2b**, *J* = 8.2 Hz), 7.70 (d, 2H, **2b'**, *J* = 8.2 Hz), 7.38 (d, 2H, **2b'**, *J* = 8.0 Hz), 7.32-7.28 (m, 5H, **2b'** and 2H, **2b**), 7.24-7.21 (m, 2H, **2b**), 7.10 (dt, 1H, **2b**, *J* = 15.5 Hz, 7.2 Hz), 6.60 (dt, 1H, **2b**, *J* = 15.5 Hz, 1.4 Hz), 6.52 (d, 1H, **2b'**, *J* = 15.9 Hz), 6.37 (dt, 1H, **2b'**, *J* = 15.8 Hz, 7.1 Hz), 6.07 (t, 1H, **2b**, *J* = 3.8 Hz), 6.04 (t, 1H, **2b'**, *J* = 3.8 Hz), 3.75 (dd, 2H, **2b'**, *J* = 7.1 Hz, *J* = 1.1 Hz), 3.70 (d, 2H, **2b**, *J* = 7.0 Hz), 3.51-3.46 (m, 2H, **2b'** and 2H, **2b**), 2.43 (s, 3H, **2b'**), 2.42 (s, 3H, **2b**), 2.07-2.04 (m, 2H, **2b**), 2.01-1.98 (m, 2H, **2b'**), 1.33-1.28 (m, 2H, **2b**), 1.18-1.14 (m, 2H, **2b'**). ^{13}C NMR (150 MHz) δ (ppm): 198.1 (Cq, **2b'**), 188.8 (Cq, **2b**), 145.4 (CH, **2b**), 144.5 (Cq, **2b'**), 144.3 (Cq, **2b**), 139.5 (Cq, **2b'**), 139.4 (Cq, **2b**), 138.2 (Cq, **2b**), 137.3 (Cq, **2b'**), 135.5 (Cq, **2b**), 135.1 (Cq, **2b'**), 134.3 (CH, **2b**), 134.2 (CH, **2b**), 133.7 (CH, **2b'**), 130.0 (CH, **2b'**), 129.4 (CH, **2b**), 129.3 (CH, **2b**), 128.6 (CH, **2b'**), 128.3 (CH, **2b**), 128.1 (CH, **2b'**), 127.5 (CH, **2b'**), 126.7 (CH, **2b**), 126.4 (CH, **2b'**), 126.7 (CH, **2b**), 125.2 (CH, **2b'**), 123.1 (CH, **2b'**), 45.2 (CH_2, **2b**), 45.1 (CH_2, **2b'**), 44.1 (CH_2, **2b'**), 39.0 (CH_2, **2b**), 22.5 (CH_2, **2b**), 22.3 (CH_2, **2b'**), 21.8 (CH_3, **2b** and **2b'**), 19.5 (CH_2, **2b**), 19.0 (CH_2, **2b'**). ESI-MS *m/z* (%) = 785 $[2M+Na]^+$ (64), 404 $[M+Na]^+$ (100), 382 $[M+H]^+$ (17). MS/MS of 382 *m/z* (%): 382 (8), 364 (6), 264 (49), 227 (60), 136 (33). IR (neat): 1698 cm^{-1}. $C_{22}H_{23}NO_3S$ (381.49): calcd. C 69.27, H 6.08, N, 3.67; found C 69.39, H 6.01, N 3.55.

(*E*)-5-phenyl-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)pent-2-en-1-one (2c): Pale yellow oil (57%), R_f 0.34 (8:2 PE/EtOAc). ^{1}H NMR (200 MHz) δ (ppm): 7.75 (d, 2H, *J* = 8.3 Hz), 7.36-7.18 (m, 7H), 7.02 (dt, 1H, *J* = 15.6 Hz, 6.7 Hz), 6.58 (d, 1H, *J* = 15.6 Hz), 6.03 (t, 1H, *J* = 3.8 Hz), 3.51-3.43 (m, 2H), 2.88-2.78 (m, 2H), 2.66-2.52 (m, 2H), 2.43 (s, 3H), 2.13-2.02 (m, 2H), 1.42-1.27 (m, 2H). ^{13}C NMR (50.2 MHz) δ (ppm): 188.9 (Cq), 146.5 (CH), 144.2 (Cq), 141.2 (Cq), 139.4 (Cq), 135.6 (Cq), 129.8 (CH), 128.5 (CH), 128.1 (CH), 127.8 (CH), 126.2 (CH), 125.4 (CH), 45.1 (CH_2), 34.6

(CH_2), 34.5 (CH_2), 22.5 (CH_2), 21.7 (CH_3), 19.6 (CH_2). ESI-MS *m/z* (%) = 813 $[2M+Na]^+$ (53), 418 $[M+Na]^+$ (100), 396 $[M+H]^+$ (8). MS/MS of 396 *m/z* (%): 396 (11), 240 (84), 213 (100). IR (neat): 1680 cm^{-1}. $C_{23}H_{25}NO_3S$ (395.52): calcd. C 69.85, H 6.37, N 3.54; found C 69.90, H 6.48, N 3.66.

(*E*)-5-((tetrahydro-2H-pyran-2-yl)oxy)-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)pent-2-en-1-one (2f): Pale yellow oil (47%). R_f 0.25 (7:3 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.74 (d, 2H, *J* = 8.3 Hz), 7.30 (d, 2H, *J* = 8.0 Hz), 7.00 (dt, 1H, *J* = 15.7 Hz, 6.9 Hz), 6.63, (dt, 1H, *J* = 15.7 Hz, 1.5 Hz), 6.08 (t, 1H, 3.9 Hz), 4.63-4.61 (m, 1H), 3.91-3.84 (m, 2H), 3.58-3.49 (m, 2H), 3.48-3.46 (m, 2H), 2.57 (qd, 2H; *J* = 6.7 Hz, 1.5 Hz), 2.42 (s, 3H), 2.08-2.05 (m, 2H), 1.85-1.79 (m, 1H), 1.74-1.68 (m, 1H), 1.61-1.55 (m, 2H), 1.54-1.49 (m, 2H), 1.35-1.31 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 188.7 (Cq), 144.2 (Cq), 144.0 (CH), 139.5 (Cq), 135.6 (Cq), 129.9 (CH), 128.7 (CH), 128.1 (CH), 125.5 (CH), 98.9 (CH), 65.8 (CH_2), 62.4 (CH_2), 45.2 (CH_2), 33.1 (CH_2), 30.7 (CH_2), 25.6 (CH_2), 22.5 (CH_2), 21.8 (CH_3), 19.6 (CH_2), 19.6 (CH_2). ESI-MS *m/z* (%) = 861 $[2M+Na]^+$ (8), 442 $[M+Na]^+$ (100). IR (neat): 1629 cm^{-1}. $C_{22}H_{29}NO_5S$ (419.54): calcd. C 62.98, H 6.97, N 3.34; found C 63.37, H 7.29, N 3.30.

1-phenyl-2-(1-tosyl-5,6-dihydropyridin-2(1H)-ylidene)ethan-1-one (2g): Yellow oil (44%). R_f 0.37 (8:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.95-7.95 (m, 2H), 7.72-7.70 (m, 2H), 7.56-7.53 (m, 1H), 7.48-7.45 (m, 3H), 7.27 (d, 2H, *J* = 8.0 Hz), 7.21-7.20 (m, 1H), 6.17 (dtd, 1H, *J* = 10.2 Hz, 4.3 Hz, 1.5 Hz), 3.96 (t, 2H, *J* = 6.0 Hz), 2.41 (s, 3H), 2.15-2.12 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 190.4 (Cq), 145.6 (Cq), 144.4 (Cq), 139.6 (Cq), 137.2 (Cq), 135.2 (CH), 132.8 (CH), 130.0 (CH), 128.7 (CH), 128.4 (CH), 127.3 (CH), 123.4 (CH), 113.3 (CH), 44.7 (CH_2), 24.7 (CH_2), 21.7 (CH_3). ESI-MS *m/z* (%) = 376 $[M+Na]^+$ (100), 354 $[M+H]^+$ (17). MS/MS of 354 *m/z* (%): 354 (16), 214 (100). $C_{20}H_{19}NO_3S$ (353.44): calcd. C 67.97, H 5.42, N 3.96; found C 67.81, H 5.60, N 3.86.

1-phenyl-2-(1-tosyl-1,2,5,6-tetrahydropyridin-2-yl)ethane-1,2-dione (3g): Yellow oil (11%). R_f 0.29 (8:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 8.18-8.16 (m, 2H), 7.72 (d, 2H, *J* = 8.3 Hz), 7.62-7.59 (m, 1H), 7.51-7.48 (m, 2H), 7.32 (d, 2H, *J* = 8.0 Hz), 6.43 (t, 1H, *J* = 6.9 Hz), 3.53-3.51 (m, 2H), 2.44 (s, 3H), 2.19 (td, 2H, *J* = 6.6 Hz, 3.9 Hz), 1.42-1.38 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 190.2 (Cq), 188.1 (Cq), 144.5 (Cq), 136.5 (Cq), 135.2 (Cq), 134.2 (CH), 132.9 (Cq), 131.0 (CH), 130.9 (CH), 130.0 (CH), 128.6 (CH), 128.0 (CH), 44.8 (CH_2), 23.1 (CH_2), 21.8 (CH_3), 19.6 (CH_2). ESI-MS *m/z* (%) = 761 $[2M+Na]^+$ (36), 392 $[M+Na]^+$ (100), 370 $[M+H]^+$ (4). MS/MS of 370 *m/z* (%): 370 (24), 229 (38), 215 (100).

(*E*)-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)-5-((triisopropylsilyl)oxy)pent-2-en-1-one (2h): Pale yellow oil (53%). R_f 0.43 (8:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.75 (d, 2H, *J* = 8.3 Hz), 7.31 (d, 2H, *J* = 7.9 Hz), 7.00 (dt, 1H, *J* = 15.1 Hz, 7.6 Hz), 6.60 (dt 1H, *J* = 15.7 Hz, 1.4 Hz), 6.06 (t, 1H, *J* = 3.9 Hz), 3.84 (t, 2H, *J* = 6.6 Hz), 3.49-3.45 (m, 2H), 2.52 (qd, 2H, *J* = 6.7 Hz, 1.4 Hz), 2.43 (s, 3H), 2.09-2.05 (m, 2H), 1.07-1.04 (m, 21H). ^{13}C NMR (150 MHz) δ (ppm): 188.9 (Cq), 144.5 (CH), 144.2 (Cq), 139.4 (Cq), 135.7 (Cq), 129.9 (CH), 128.9 (CH), 128.1 (CH), 125.3 (CH), 62.2 (CH_2), 45.2 (CH_2), 36.5 (CH_2), 22.5 (CH_2), 21.8 (CH_3), 19.7 (CH_2), 18.2 (CH_3), 12.1 (CH). ESI-MS *m/z* (%) = 1005 $[2M+Na]^+$ (100), 514 $[M+Na]^+$ (98), 493 $[M+H]^+$ (7), 492 $[M]^+$ (22). MS/MS of 492 *m/z* (%): 492 (16), 292 (100). IR (neat): 1629 cm^{-1}. $C_{26}H_{41}NO_4SSi$ (491.76): calcd. C 63.50, H 8.40, N 2.85; found C 63.22, H 8.31, N 2.87.

(*E*)-1-(1-tosyl-4,5,6,7-tetrahydro-1H-azepin-2-yl)hex-2-en-1-one (2i): Yellow oil (84%). R_f 0.50 (8:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.80 (d, 2H, *J* = 8.3 Hz), 7.29 (d, 2H, *J* = 7.9 Hz), 7.00 (dt, 1H, *J* = 15.4 Hz, 7.0 Hz), 6.73 (t, 1H, *J* = 6.8 Hz), 6.57 (dt, 1H, *J* = 15.4 Hz, 1.5 Hz), 3.53-3.49 (m, 2H), 2.42 (s, 3H), 2.23 (qd, 2H, *J* = 7.2 Hz, 1.5 Hz), 2-08-2.04 (m, 2H), 1.71-1.67 (m, 2H), 1.52 (sext,2H *J* = 7.4 Hz), 1.41-1.37 (m, 2H), 0.95 (t, *J* = 7.4 Hz). ^{13}C NMR (150 MHz) δ (ppm): 188.7 (Cq), 149.1 (CH), 143.7 (Cq), 143.0 (Cq), 138.7 (CH), 137.8 (Cq), 129.7 (CH), 128.0 (CH), 126.1 (CH), 49.5 (CH_2), 34.9 (CH_2), 29.0 (CH_2), 26.9 (CH_2), 23.0 (CH_2), 21.7 (CH_3), 21.6 (CH_2), 13.9 (CH_3). GC-MS *m/z* (%) = 347 $[M]^+$ (3), 304 (26), 240 (100), 192 (100), 149 (35), 97 (43), 91 (43), 55 (44). IR (neat): 1676 cm^{-1}. $C_{19}H_{25}NO_3S$ (347.47): calcd. C 65.68; H 7.25, N 4.03; found C 65.89, H 7.31, N 7.13.

(*E*)-1-(3,4-dihydro-2H-pyran-6-yl)-4-phenylbut-2-en-1-one (2j): Pale yellow oil (56%). R_f 0.28 (9:1 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.31 (t, 2H, *J* = 7.2 Hz), 7.25-7.21 (m, 1H), 7.19-7.17 (m, 2H), 7.13 (dt, 1H, *J* = 15.4 Hz, 6.9 Hz), 6.66 (dt, 1H, *J* = 15.4 Hz, 1.6 Hz), 5.99 (t, 1H, *J* = 4.3 Hz), 4.11-4.09 (m, 2H), 3.56 (dd, 2H, *J* = 6.9 Hz, 1.3 Hz), 2.22 (td, 2H, *J* = 6.4 Hz 4.3 Hz), 1.88-1.84 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 185.6 (Cq), 151.8 (Cq), 146.7 (CH), 138.1 (Cq), 129.0 (CH), 128.8 (CH), 126.7 (CH), 125.1 (CH), 111.3 (CH), 66.3 (CH_2), 39.1 (CH_2), 21.7 (CH_2), 21.0 (CH_2). GC-MS *m/z* (%) = 228 $[M]^+$ (100), 145 (21), 137 (53), 127 (38), 115 (65), 111 (62), 91 (45), 55 (42). IR (neat): 1671 cm^{-1}. $C_{15}H_{16}O_2$ (228.29): calcd. C 78.92, H 7.06; found C 78.66, H 7.28.

(*E*)-4-phenyl-1-(1-tosyl-1,4,5,6-tetrahydropyridin-2-yl)but-3-en-1-one (2j'): Pale yellow oil. R_f 0.35 (9:1 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.38-7.36 (m, 2H), 7.31-7.28 (m, 2H), 7.23-7.20 (m, 1H), 6.47 (d, 1H, *J* = 16.0 Hz), 6.36 (dt, 1H, *J* = 15.9 Hz, 6.9 Hz), 6.03 (t, 1H, *J* = 4.3 Hz), 4.12-4.10 (m, 2H), 3.54 (dd,2H, *J* = 6.9 Hz, 1.4 Hz), 2.24-2.20 (m, 2H), 1.89-1.85 (m, 2H). ^{13}C NMR (150 MHz): 194.6 (Cq), 151.1 (Cq), 137.3 (Cq), 133.4 (CH), 128.6 (CH), 127.5 (CH), 126.4 (CH), 122.7 (CH), 110.3 (CH), 66.5 (CH_2), 41.8 (CH_2), 21.7 (CH_2), 20.9 (CH_2). GC-MS *m/z* (%) = 228 $[M]^+$ (47), 137 (13), 117 (30), 115 (28), 111 (100), 91 (21).

(*E*)-1-(3,4-dihydro-2H-pyran-6-yl)hex-2-en-1-one (2k): Pale yellow oil (46%). R_f 0.45 (9:1 PE/EtOAc + 0.1% Et_3N). ^{1}H NMR (600 MHz) δ (ppm): 7.01 (dt, 1H, *J* = 15.4 Hz, 7.0 Hz), 6.66 (dt, 1H, *J* = 15.4 Hz, 1.5 Hz), 6.01 (t, 1H, *J* = 4.3 Hz), 4.12-4.10 (m, 2H), 2.24-2.19 (m, 2H), 1.88-1.84 (m, 2H), 1.50 (sext, 2H, *J* = 7.4 Hz)), 0.93 (t, 3H, *J* = 7.4 Hz). ^{13}C NMR (150 MHz) δ (ppm): 185.7 (Cq), 151.9 (Cq), 148.9 (CH), 124.3 (CH), 123.0 (Cq), 102.0 (CH), 66.5 (CH_2), 34.9 (CH_2), 21.7 (CH_2), 21.5 (CH_2), 21.0 (CH_2), 13.5 (CH_3). GC-MS *m/z* (%) = 180 $[M]^+$ (27), 137 (100), 97 (53), 55 (73). IR (neat): 1702 cm^{-1}. $C_{11}H_{16}O_2$ (180.25): calcd. C 73.30, H 8.95; found C 73.12, H 8.86.

(*E*)-1-(3,4-dihydro-2H-pyran-6-yl)-5-phenylpent-2-en-1-one (2m): Pale yellow oil (54%). R_f 0.25 (9:1 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.29 (t, 2H, *J* = 7.5 Hz), 7.21-7.17 (m, 3H), 7.04 (dt, 1H, *J* = 15.4 Hz, 6.9 Hz), 6.67 (dt, 1H, *J* = 15.4 Hz, 1.5 Hz), 5.98 (t, 1H, *J* = 4.3 Hz), 4.12-4.10 (m, 2H), 2.81-2.78 (m, 2H), 2.58-2.43 (m, 2H), 2.24-2.20 (m, 2H), 1.88-1.84 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 185.6 (Cq), 151.8 (Cq), 147.6 (CH), 141.0 (Cq), 128.6 (CH), 128.5 (CH), 126.2 (CH), 124.7 (CH), 111.2 (CH), 66.5 (CH_2), 34.6 (CH_2), 34.6 (CH_2), 21.7 (CH_2), 21.0 (CH_2). GC-MS *m/z* (%) = 242 $[M]^+$ (20), 151 (17), 91 (100). IR (neat): 1702 cm^{-1}. $C_{16}H_{18}O_2$ (242.32): calcd. C 79.31, H 7.49; found C 79.68, H 7.30.

(*E*)-1-(3,4-dihydro-2H-pyran-6-yl)-5-((tetrahydro-2H-pyran-2-yl)oxy)pent-2-en-1-one (2n): Pale yellow oil (546%), R_f 0.40 (8:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.01 (dt, 1H, *J* = 15.5 Hz, 6.9 Hz), 6.74 (dt, 1H, *J* = 15.6 Hz, 1.5 Hz), 6.02 (t, 1H, *J* = 4.3 Hz), 4.60-4.59 (m, 1H), 4.11-4.09 (m, 2H), 3.89-3.81 (m, 2H), 3.54-3.48 (m, 2H), 2.53 (qd, 2H, *J* = 6.7 Hz, 1.5 Hz), 2.24-2.21 (m, 2H), 1.88-1.84 (m, 2H), 1.82-1.77 (m, 1H), 1.72-1.67 (m, 1H), 1.60-1.55 (m, 2H), 1.53-1.49 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 185.5 (Cq), 151.8 (Cq), 145.2 (CH), 125.6 (CH), 111.2 (CH), 98.9 (CH), 66.5 (CH_2), 65.8 (CH_2), 62.4 (CH_2), 33.2 (CH_2), 30.7 (CH_2), 25.6 (CH_2), 21.7 (CH_2), 21.0 (CH_2), 19.6 (CH_2). GC-MS *m/z* (%) = 166 $[M]^+$ (43), 111 (27), 85 (100). IR (neat): 1727 cm^{-1}. $C_{15}H_{22}O_4$ (166.34): calcd. C 67.65, H 8.33; found C 67.76, H 67.85.

(*E*)-1-(4,5,6,7-tetrahydrooxepin-2-yl)hex-2-en-1-one (2o):[31] Pale yellow oil (39%). R_f 0.35 (95:5 PE/EtOAc). ^{1}H NMR (200 MHz, $CDCl_3$) δ (ppm): 6.98 (dt, 1H, *J* = 15.4 Hz, 6.8 Hz), 6.71 (d, 1H, *J* = 15.5 Hz), 6.31 (t, 1H, *J* = 6.2 Hz), 4.04-3.96 (m, 2H), 2.40-2.14 (m, 4H), 1.98-1.85 (m, 2H), 1.76-1.57 (m, 2H), 1.56-1.40 (m, 2H), 0.93 (t, 3H, *J* = 7.4 Hz). GC-MS *m/z* (%) = 194 $[M]^+$ (19), 151 (100), 97 (65), 55 (89).

(*E*)-1-(1-methyl-1H-indol-2-yl)hex-2-en-1-one (2p): Yellow oil (12%). R_f 0.28 (98:2 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 7.69 (dt, 1H, *J* = 8.0 Hz, 1.0 Hz), 7.40-7.36 (m, 2H), 7.29 (s, 1H), 7.16-7.13 (m, 1H), 7.07 (dt, *J* = 15.3 Hz, 6.9 Hz), 6.92 (dt, 1H, *J* = 15.3 Hz, 1.5 Hz), 4.10 (s, 3H), 2.30 (qd,2H, *J* = 7.2 Hz, 1.5 Hz), 1.57 (sext,2H, *J* = 7.2 Hz), 0.98 (t, 3H, *J* = 7.2 Hz). ^{13}C NMR (150 MHz) δ (ppm): 183.4 (Cq), 147.7 (CH), 140.5 (Cq), 136.1 (Cq), 127.5 (CH), 126.1 (Cq), 126.0 (CH), 123.1 (CH), 120.8 (CH), 111.6 (CH), 110.5 (CH), 34.8 (CH_2), 32.4 (CH_3), 21.7 (CH_2), 13.9 (CH_3). GC-MS *m/z* (%) = 227 $[M]^+$ (38), 184 (100). $C_{15}H_{17}NO$ (227.31): calcd. C 79.26, H 7.54, N 6.16; found C 79.08, H 7.32, N 6.49.

5-benzyl-1-tosyl-1,2,3,4,5,6-hexahydro-7H-cyclopenta[b]pyridin-7-one (4b):[32] The crude divinyl ketone **2b** was not purified, but was dissolved in TFA (0.1-0.2 M) at 0 °C. The mixture was stirred at room temperature for 1.5 hours, then a saturated $NaHCO_3$ solution was added. The mixture was extracted with CH_2Cl_2 (3x5 ml); the combined organic layers were dried over Na_2SO_4, filtered and the solvent was removed under reduced pressure. The crude bicyclic ketone was purified by flash chromatography to give pure **4b** as a yellow oil (35%, 2-step). R_f 0.38 (7:3 PE/EtOAc). ^{1}H NMR (600 MHz) δ (ppm): 8.00 (d, 2H, *J* = 8.4 Hz), 7.33-7.30 (m, 4H), 7.25-7.22 (m, 1H), 7.17 (d, 2H, *J* = 7.0 Hz), 3.51-3.47 (m, 1H), 3.43-3.38 (m, 1H), 3.14-3.10 (m, 1H), 3.12 (dd, 1H, *J* = 13.4 Hz, 5.0 Hz), 3.09-3.05 (m, 1H), 2.54 (dt,1H, *J* = 19.8 Hz, 6.8 Hz), 2.48-2.55 (m, 1H), 2.42 (s, 3H), 2.30 (dt, 1H, *J* = 19.8 Hz, 6.4 Hz), 2.19 (dd, 1H, *J* = 18.4 Hz, 1.9 Hz), 2.05-2.04 (m, 2H). ^{13}C NMR (150 MHz) δ (ppm): 199.6 (Cq), 161.5 (Cq), 143.7 (Cq), 139.1 (Cq), 138.2 (Cq), 138.0 (Cq), 129.5 (CH), 128.8 (CH), 127.9 (CH), 126.8 (CH), 46.2 (CH_2), 40.9 (CH), 40.0 (CH_2), 40.0 (CH_2), 24.4 (CH_2), 22.0 (CH_2), 21.7 (CH_3). ESI-MS *m/z* (%) = 785 $[2M+Na]^+$ (93), 404 $[M+Na]^+$ (100), 382 $[M+H]^+$ (15). MS/MS of 382 *m/z* (%): 382 (4), 226 (100), 136 (77). IR (neat): 1709 cm^{-1}. $C_{23}H_{23}NO_3S$: calcd. C 69.27, H 6.08, N 3.67; found C 69.03, H 6.42, N 3.75.

4-methyl-1-propyl-1,4-dihydrocyclopenta[b]indol-3(2H)-one (4p): The same procedure as for **4b**, starting from pure divinyl ketone **2p**, afforded pure **4p** as a yellow oil (91%). ^{1}H NMR (600 MHz) δ (ppm): 7.73 (dt, 1H, *J* = 8.1 Hz, 0.9 Hz), 7.43-7.40 (m, 1H), 7.37 (dt, 1H, *J* = 8.5 Hz, 0.9 Hz), 7.19-7.16 (m, 1H), 3.91 (s, 3H), 3.49-3.45 (m, 2H), 3.14 (dd, 1H, *J* = 18.2 Hz, 6.2 Hz), 2.62 (dd, 1H, *J* = 18.2 Hz, .9 Hz), 1.99-1.93 (m, 1H), 1.63-1.58 (m, 1H), 1.53-1.46 (m, 2H), 0.99 (t, 3H, *J* = 7.3 Hz). ^{13}C NMR (150 MHz) δ (ppm): 194.7 (Cq), 148.6 (Cq), 145.0 (Cq), 138.5 (Cq), 126.8 (CH), 123.0 (Cq), 122.4 (CH), 120.3 (CH), 111.2 (CH), 48.7 (CH_2), 38.3 (CH_2), 33.7 (CH_3), 30.2 (CH), 21.2 (CH_2), 14.4 (CH_3). GC-MS *m/z* (%) = 227 $[M]^+$ (27), 184 (100). $C_{15}H_{17}NO$ (227.31): calcd. C 79.26, H 7.54, N 6.16; found C 78.96, H 7.72, N 6.29.

Acknowledgements

Financial support from the University of Turin is acknowledged. We thank the Cost Association STREAM FA1206 “Strigolactones: biological roles and applications”, Compagnia di San Paolo Foundation for their support (proJect Stritool). EGO thanks the MIUR and the University of Florence for support. Part of this work is included in Simone Ghinato MD thesis.

Keywords: gold catalysis, gold catalysed oxidation, lactam derived heterocycles, Nazarov reaction.

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10.1002/ejoc.201701212

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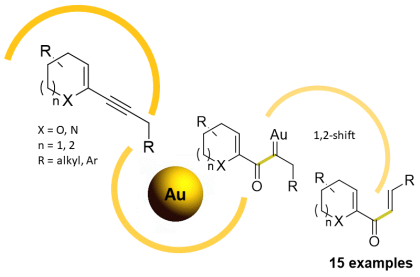
Layout 1:

FULL PAPER

The gold catalysed oxidation of heterocycle derived enynes successfully affords divinyl ketones in which one of the double bond is embedded in a heterocycle. The obtained divinyl ketones are then easily cyclized according to a Nazarov process and the bi or polycyclic compounds used as scaffold in the synthesis of analogues of plant hormones Strigolactones



*****Heterocyclic divinyl ketones from enynes

Oxidative Gold catalysis*

Stefano Nejrotti, Gabriele Prina Cerai, Alberto Oppedisano, Andrea Maranzana, Ernesto G. Occhiato, Dina Scarpi, Annamaria Deagostino and Cristina Prandi

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A gold(I)-catalyzed oxidative rearrangement of heterocycle derived 1,3-enynes provides an efficient and selective route to divinyl ketones