# REACTIVE INTERMEDIATES NOTES

Carbenes

These are neutral, divalent, highly reactive carbon intermediates. The two non-bonding electrons can be arranged parallel or spin-paired. Spin-paired show both electrons an sp^2 orbital, leaving the p orbital vacant. This is the singlet state. The triplet state shows both electrons with parallel spins and leaves one electron in an sp^2 orbital and the other in a p orbital, and this is the triplet state.
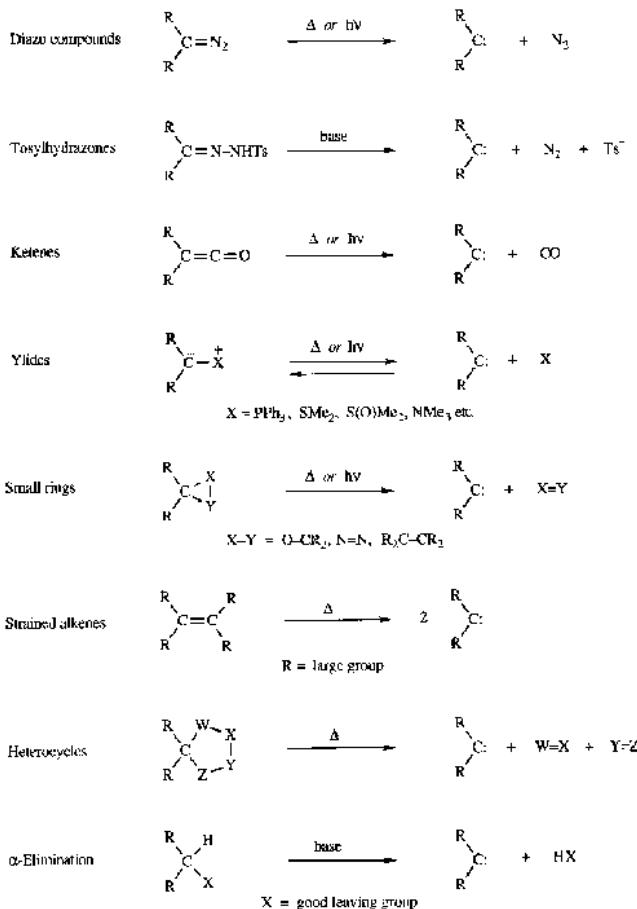
Structure –
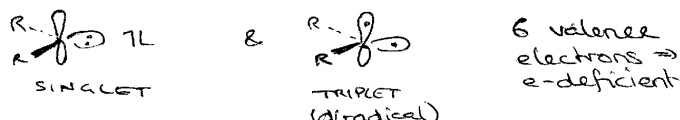
Evidence of this is provided by UV, IR, and particularly ESR.
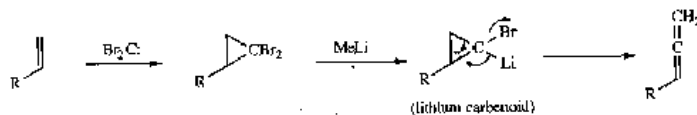
Stability –
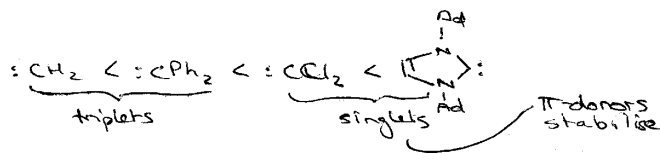
Generation –
There are several methods for generation of carbenes, which are listed below.

The most common method is α-elimination. This can be modified to generate carbenoids:


Carbenes undergo many reactions.

Cycloaddition –
1,2-addition of carbenes to alkenes to form cyclopropanes. This is basically addition to a double bond.

The Skell Hypothesis states that a singlet carbene can add to a double bond in a single step and is stereospecific, while the triplet carbene cannot since it is spin forbidden:

Stereospecific addition of singlet carbenes to alkenes

Non-stereospecific addition of triplet carbenes to alkenes
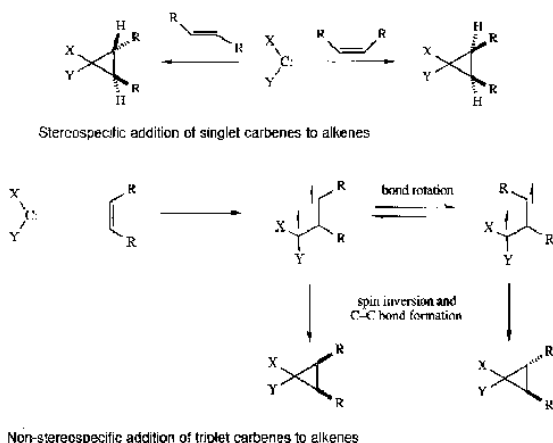
It should also be noted that in addition to allenes, the singlet carbene will add at the more substituted double bond, while triplet at the less substituted.
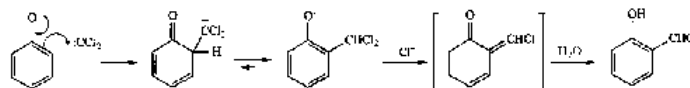
Carbenes will also add to alkynes (although less readily, since alkynes are less nucleophilic than alkenes), and to arenes. The latter generates a 7-membered ring with 3 double bonds:

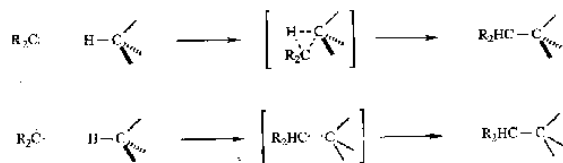A similar molecule could be attacked by carbenes itself, e.g.
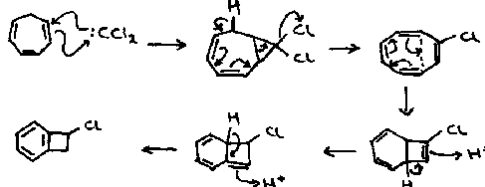
One particular mechanism is the Riemer-Tiemann Reaction:

Insertion –
Characteristic reaction of carbenes to insert into a single bond, often C-H. Again two mechanisms can be conceived depending on spin:
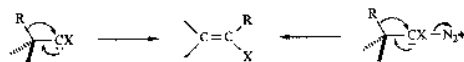
This is often termed hydrogen abstraction as well.
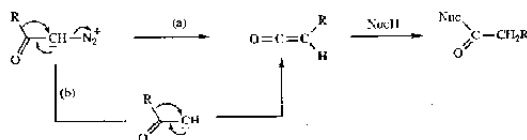It only occurs with very reactive carbenes, and often shows poor regioselectivity.

Rearrangement –
The vacant p-orbital allows for easy rearrangement to occur in a similar way to Carbocations:
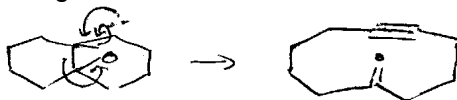
This is very fast. R is usually a H (C-C is very rare).

Wolff Rearrangement of diazoketones to ketenes is a famous mechanism, and occurs as:
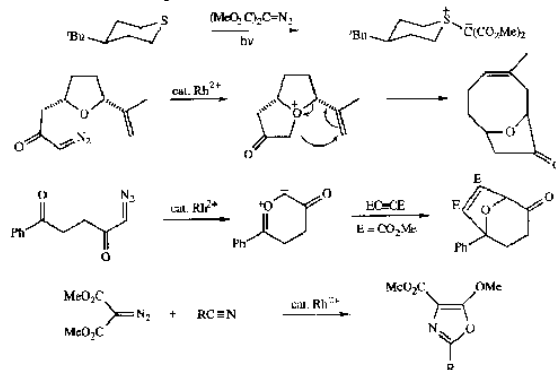
The Eschenmoser Rearrangement also involves carbenes:
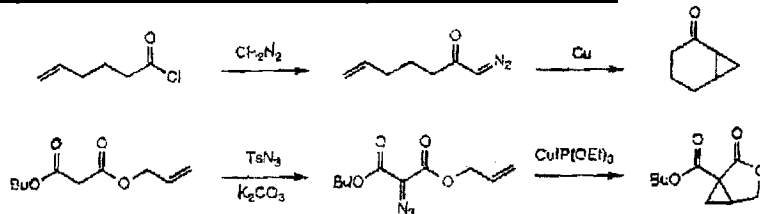
Reaction with Nucleophiles –
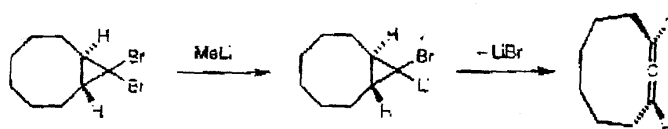Common since carbenes are very electron deficient.

Carbenoids
Similar to carbenes, but involve a metal bonded to the carbene. Some of their reactions include:
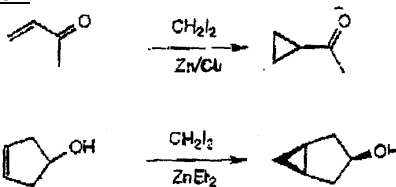
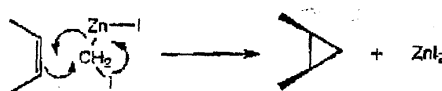Metal Catalysed Reaction of Diazo Compounds with Alkenes

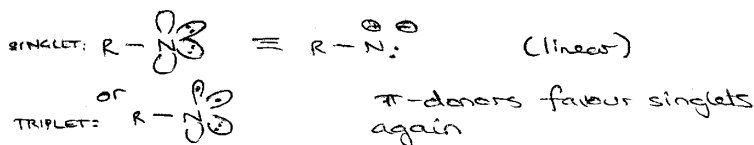α-halo-organometallics

Simmons-Smith Cyclopropanation
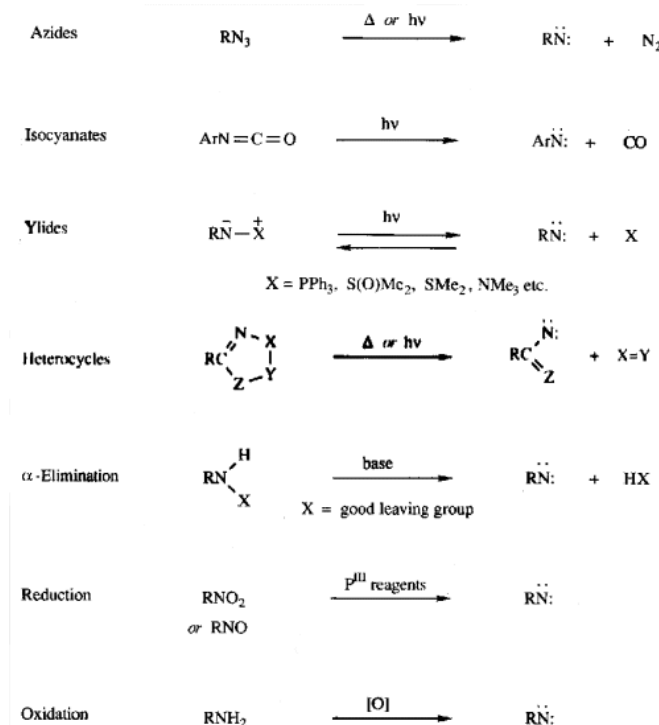

mechanism:

Nitrenes

Six-electron, neutral, monovalent, highly reactive intermediates. The N atom has 4 non-bonded electrons. There are triplet and singlet states, as for carbenes.

They are isoelectronic with carbenes, but have 6 π electrons instead. Similar chemistry is seen, although on the whole they are more reactive.

Structure –

SINGLET: $R-N$ ≡ $R-\overset{\ominus\ominus}{N}:$ (linear)

or

TRIPLET: $R-N$ π-donors favour singlets again

Generation –

|			
Azides	RN_3	$\xrightarrow{\Delta \ or \ h\nu}$	$R\ddot{N}: + N_2$
Isocyanates	$ArN=C=O$	$\xrightarrow{h\nu}$	$Ar\ddot{N}: + CO$
Ylides	$R\bar{N}-\overset{+}{X}$	$\xrightleftharpoons{h\nu}$	$R\ddot{N}: + X$
		$X = PPh_3, S(O)Me_2, SMe_2, NMe_3$ etc.	
Heterocycles		$\xrightarrow{\Delta \ or \ h\nu}$	$+ X=Y$
α-Elimination	$RN\overset{H}{\underset{X}{\diagup}}$	$\xrightarrow{base}$	$R\ddot{N}: + HX$
		$X = $ good leaving group	
Reduction	RNO_2 or RNO	$\xrightarrow{P^{III} \ reagents}$	$R\ddot{N}:$
Oxidation	RNH_2	$\xrightarrow{[O]}$	$R\ddot{N}:$

They undergo the same sort of reactions as carbenes, and often with the same mechanisms, although obviously generating C-N bonds instead.

Some reactions:

Addition to C=C (as for carbenes). Have to watch for competing 1,3-dipolar cycloaddition with azides.
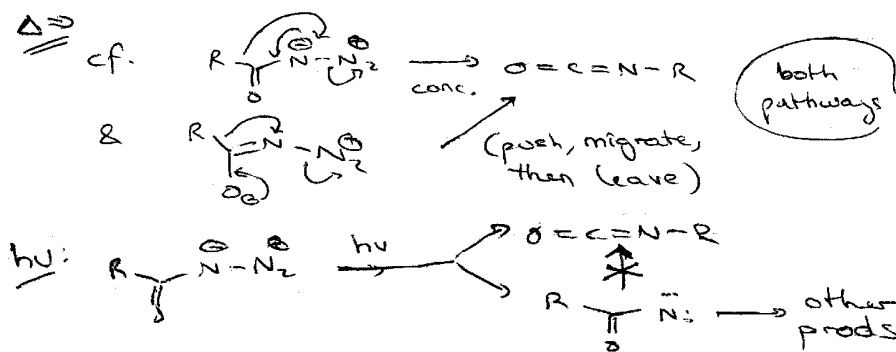**Insertion** (as for carbenes).
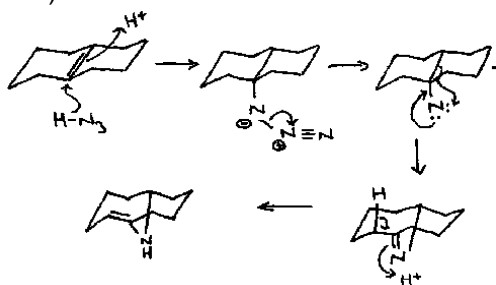
Rearrangements –
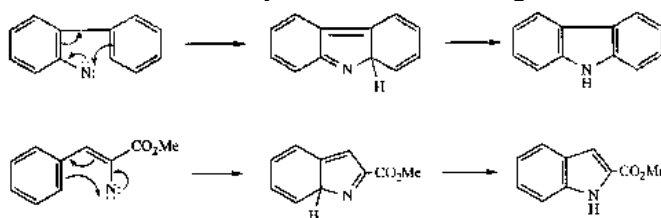1,2-shift (as for carbenes).
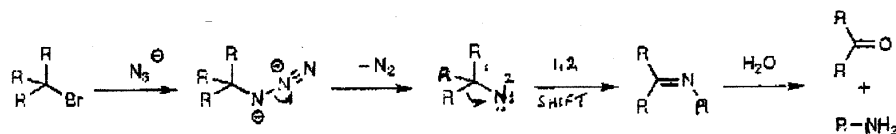Acyl azide – concerted with nitrene formation.
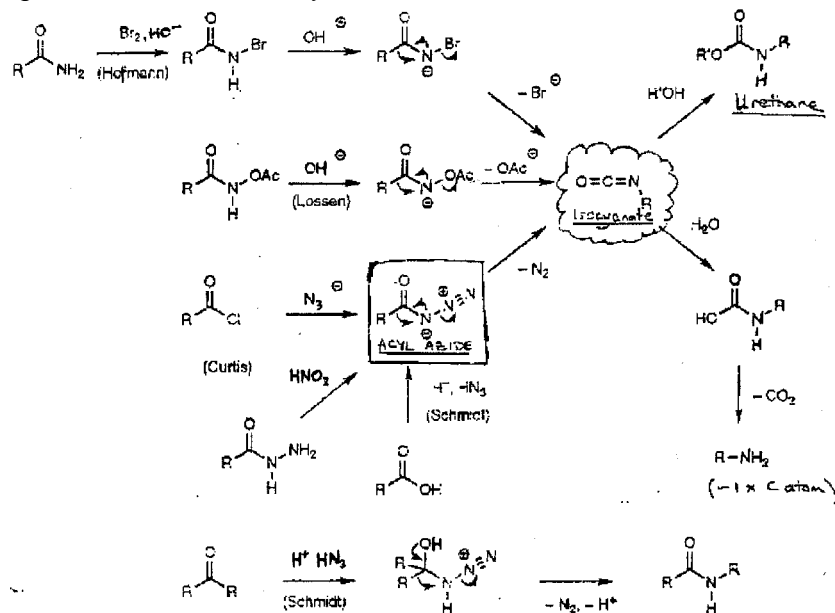Under heat ➔ **no** acylnitrene.

One other particular reaction that they are useful for is ring closure:
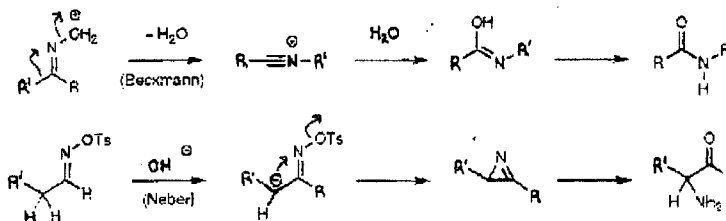

<u>Rearrangements Involving Nitrene Intermediates</u>

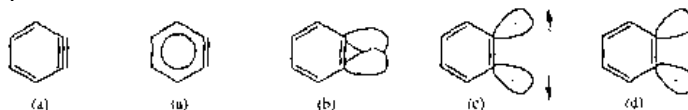Rearrangements Which Probably do not involve Nitrene Intermediates

Other Rearrangements involving Electron Deficient Nitrogen
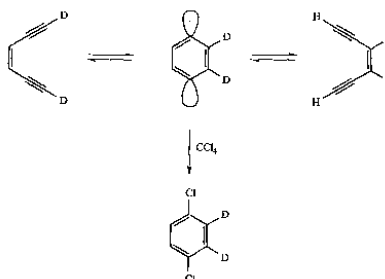
Arynes

Ortho-benzyne can take either singlet or triplet diradical structures, but is typical drawn as a simple Lewis structure:

Representations of ortho-benzyne showing (a) the alkyne structure resulting from (b) lateral overlap of the two p-orbitals, and (c) singlet and (d) triplet diradical structures

Most of the chemistry follows the alkyne structure, as opposed to the singlet or triplet diradical. It can be stabilised by complexing to transition metals.

Meta and Para benzynes are also known, although these require the diradical form. A classic reaction of para-benzyne is the Bergman Cyclisation:
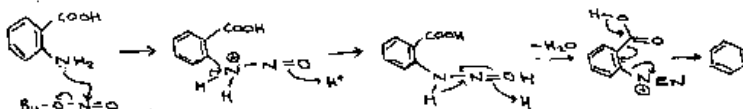
There are a number of methods of generating Arynes. Some of these are:
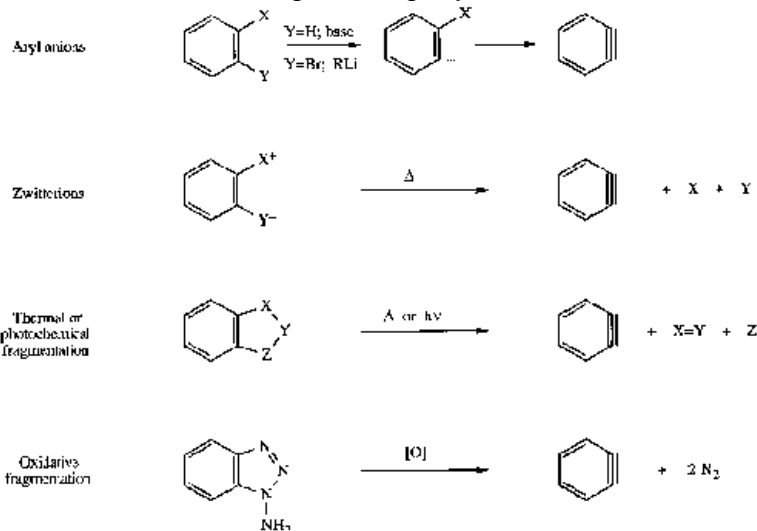
Aryl anions typically require abstraction of a halide from the benzene ring. A strong base will be present.

Zwitterions usually involve the loss of N_2 via attack by NH_2 on HONO or similar:
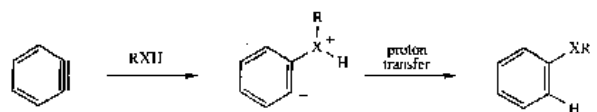

Fragmentation is thermodynamically favourable if the fragments are highly stable, e.g. CO_2 or N_2 formed. This also applies for oxidative fragmentation, as in:
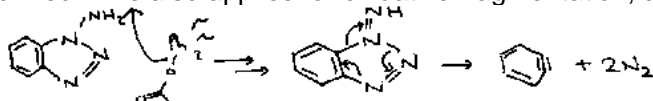

In terms of reactivity, Arynes are actually electron-deficient and highly electrophilic as a result. They are classed as "soft" due to low lying LUMOs and highly polarisable orbitals.
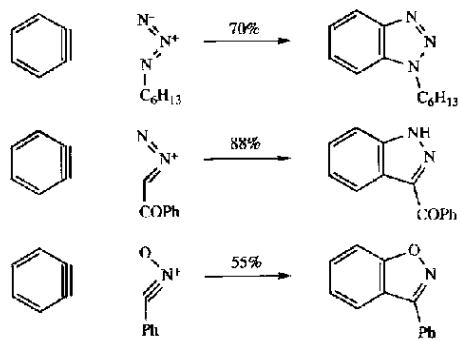
They react as:

Addition of heteroatom nucleophiles to *ortho*-benzyne: e.g. RXH = H_2O, ROH, RCO_2H, RSH, RNH_2, R_2NH

They also react in cycloaddition reactions, although this requires the absence of any nucleophiles because the reaction above is extremely facile. This reactions such as Diels-Alder can be observed. They will also react with alkenes in a similar way:
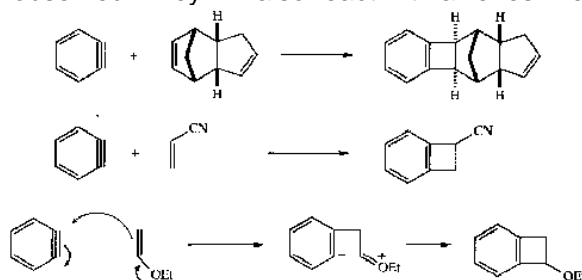
Of further note, 1,3-dipolar cycloaddition is evident:

Also the ene reaction: