Overall:

$$R\overset{\overset{O}{\|}}{-}Cl \xrightarrow[\text{BENZENE}]{\text{NaN}_3} R\overset{\overset{O}{\|}}{-}N_3 \xrightarrow[\substack{2)\ \text{MeOH} \\ 3)\ H_3O^{\oplus}}]{1)\ \Delta} R-NH_2$$
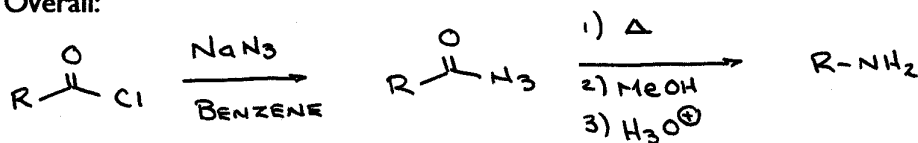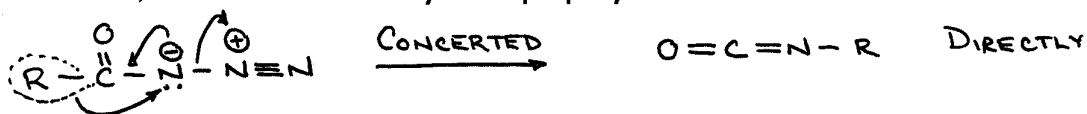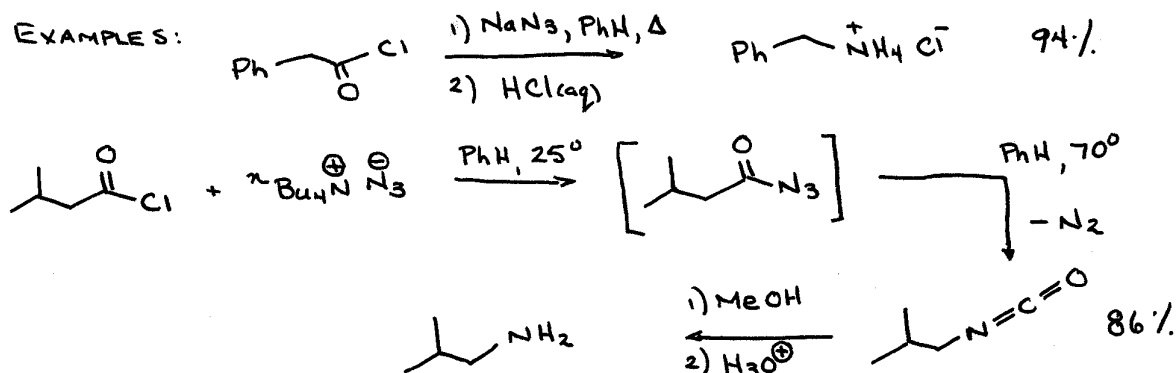
This is the conversion of a carboxylic acid (by its acid chloride) to an amine with <u>one less carbon</u>.

Another lie has been told here for the sake of clarity. The truth appears to be that the loss of N_2 from the acyl azide and migration of the R group are probably concerted. No discrete nitrene has even been isolated or trapped from this reaction, and it's doubtful that one ever actually exists. As a result, the mechanism is really more properly written as:
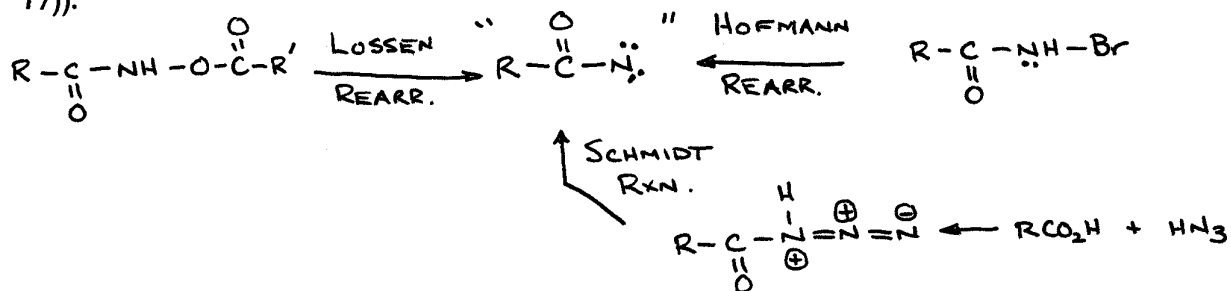
$$R\overset{\overset{O}{\|}}{-}\overset{\ominus}{C}-\overset{\oplus}{N}-N\equiv N \xrightarrow{\text{CONCERTED}} O=C=N-R \qquad \text{DIRECTLY}$$

EXAMPLES:

$$Ph\overset{\overset{O}{\|}}{\frown}Cl \xrightarrow[\substack{2)\ HCl(aq)}]{1)\ NaN_3,\ PhH,\ \Delta} Ph\frown\overset{+}{N}H_4\ Cl^- \qquad 94\cdot/.$$

$$\overset{\overset{O}{\|}}{\bigwedge}Cl + {}^n Bu_4\overset{\oplus}{N}\ \overset{\ominus}{N}_3 \xrightarrow{PhH,\ 25^\circ} \left[\overset{\overset{O}{\|}}{\bigwedge}N_3\right] \xrightarrow[-N_2]{PhH,\ 70^\circ} \bigwedge N=C=O \qquad 86\cdot/.$$

$$\bigwedge NH_2 \xleftarrow[2)\ H_3O^{\oplus}]{1)\ MeOH}$$

Aside:

There are several other reactions which are essentially the Curtius rearrangement, but go by another name. The only difference the method of generation of this 'putative' nitrene. (see Lossen rearrangement (March 8-16), Hofmann rearrangement (March 8-14), Schmidt reaction (March 8-17)).

$$R-\overset{\overset{O}{\|}}{C}-NH-O-\overset{\overset{O}{\|}}{C}-R' \xrightarrow[\text{REARR.}]{\text{LOSSEN}} R-\overset{\overset{O}{\|}}{C}-\ddot{N}: \xleftarrow[\text{REARR.}]{\text{HOFMANN}} R-\overset{\overset{O}{\|}}{C}-NH-Br$$

$$\overset{\uparrow\ \text{SCHMIDT}}{\underset{\text{RXN.}}{}}$$

$$R-\overset{\overset{O}{\|}}{C}-\overset{\overset{H}{|}}{\underset{\oplus}{N}}=\overset{\oplus}{N}=\overset{\ominus}{N} \xleftarrow{} RCO_2H + HN_3$$

## Beckmann Rearrangement (March 8-18)

Like the Curtius rearrangement, the Beckmann rearrangement involves the migration of an alkyl group to an electron deficient N atom. This time, however, there is a charge (+) involved. This rearrangement starts with an oxime, which is an imine-like derivative of a ketone .
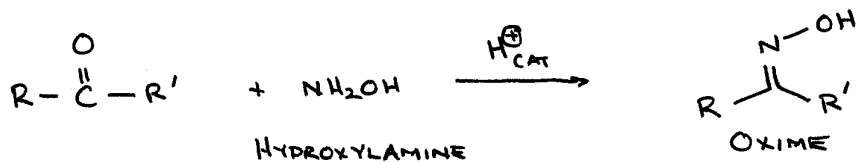
Oximes do have geometric isomers, like alkenes. Not surprisingly, the oxime which is normally formed has the OH *cis* to the smaller R group.

Rearrangement of these can be induced by subjecting these oximes to strong protic acid (i.e., H_2SO_4) or Lewis acid (i.e., PCl_5). The rearrangement itself is very much like a Baeyer-Villiger, involving an N instead of an O. The final product is a 2° amide. This works very well for both cyclic cases and acyclic cases.


AMIDE TAUTOMER

OVERALL:
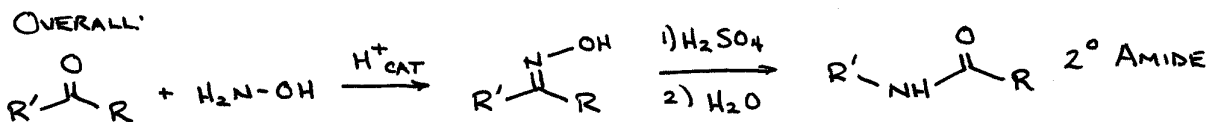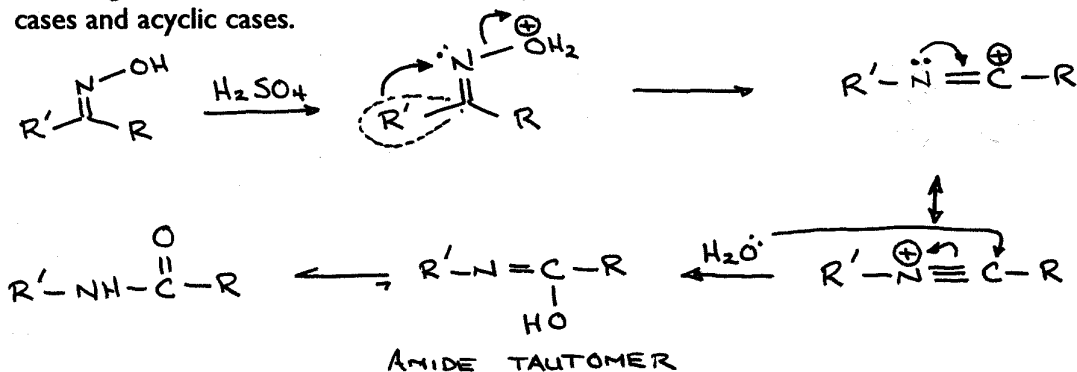
Regiochemistry: The question then arises as to which of the two R groups on the ketone (or aldehyde) migrates.

    Again, the answer is quite similar to the Baeyer-Villiger. The migrating ability is based on the ability of the potential migrating group to stabilize + charge in the transition state. SO the order is..
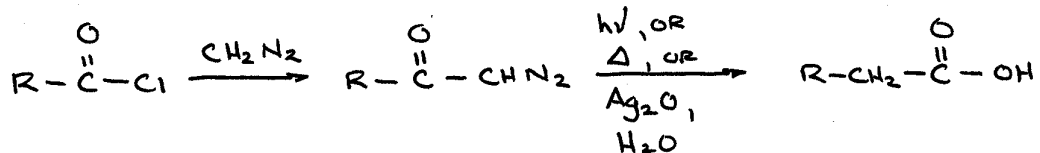
    3° alkyl > 2° alkyl > 1° alkyl > methyl
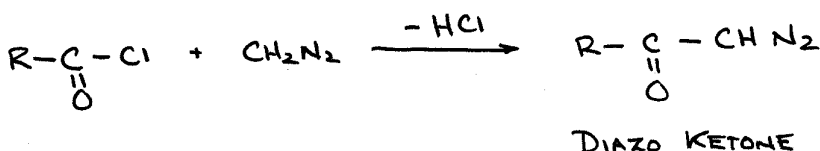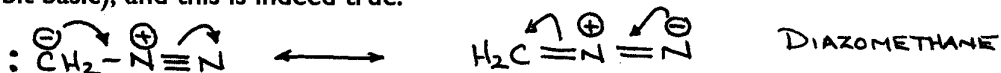   -curiously, an H atom very seldom migrates.

LACTAM
(CYCLIC AMIDE)

FAVOURED   LESS FAVOURED
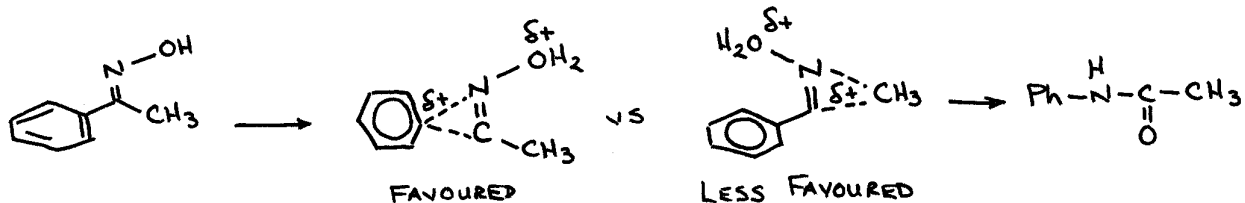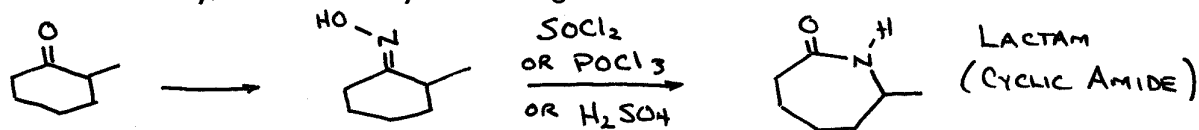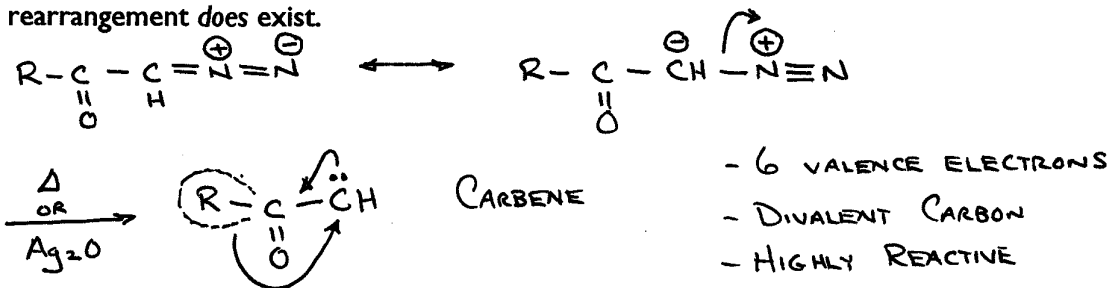
Arndt-Eistert Synthesis

The **Arndt-Eister synthesis** is actually a two step procedure, the rearrangement part of which is called the **Wolff rearrangement**. The rearrangement portion features the generation of a **carbene** from a diazo ketone. This should therefore look very much like the carbon version of a Curtius rearrangement. The overall transformation is the conversion of an acid chloride (which is a simple derivative of an acid) to an acid with one more C atom in the chain.

$$R-\overset{\overset{O}{\|}}{C}-Cl \xrightarrow{CH_2N_2} R-\overset{\overset{O}{\|}}{C}-CHN_2 \xrightarrow[\substack{Ag_2O, \\ H_2O}]{\substack{h\nu, OR \\ \Delta, OR}} R-CH_2-\overset{\overset{O}{\|}}{C}-OH$$
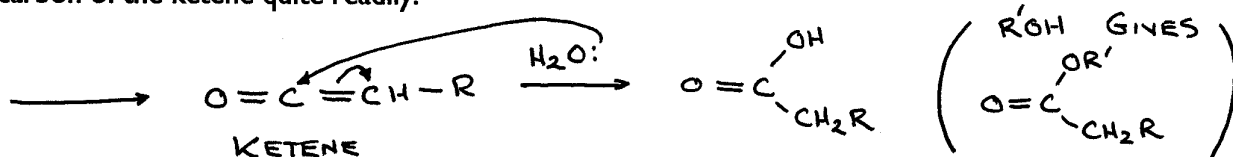
Diazoalkanes are neutral species that can be described best by two resonance forms. The left resonance form contribution suggests that these are nucleophilic at carbon (in fact, they also are a bit basic), and this is indeed true.

$$:\overset{\ominus}{C}H_2 - \overset{\oplus}{N} \equiv N \longleftrightarrow H_2C = \overset{\oplus}{N} = \overset{\ominus}{N} \qquad \text{DIAZOMETHANE}$$

$$R-\overset{\overset{\|}{O}}{C}-Cl + CH_2N_2 \xrightarrow{-HCl} R-\overset{\overset{\|}{O}}{C}-CHN_2$$

DIAZO KETONE

Thermolysis (or photolysis or treatment by Ag^{+1} salts) of the indicated diazoalkanes generates the carbene. A carbene is divalent at carbon, which means there are only six valence electrons; therefore, they are both electron deficient and highly reactive. Unlike the Curtius rearrangement, evidence for the existence of the carbene as a short-lived intermediate in the Wolff rearrangement *does* exist.

$$R-\overset{\overset{\|}{O}}{C}-\overset{\overset{|}{H}}{C}=\overset{\oplus}{N}=\overset{\ominus}{N} \longleftrightarrow R-\overset{\overset{\|}{O}}{C}-\overset{\ominus}{C}H-\overset{\oplus}{N}\equiv N$$

$$\xrightarrow[Ag_2O]{\Delta} \overset{\cdot\cdot}{R-C-CH} \qquad \text{CARBENE}$$
$$\qquad\qquad \overset{\|}{O}$$

- 6 VALENCE ELECTRONS
- DIVALENT CARBON
- HIGHLY REACTIVE

The electron deficiency of the carbene is again relieved by migration of the R group on the carbonyl, along with its bonding electron pair (much like the Curtius). The result, a ketene, is also pretty reactive, and either water (to give the acid) or alcohols (to give the ester) attack the carbonyl carbon of the ketene quite readily.

$$\longrightarrow O=C=CH-R \xrightarrow{H_2O:} O=C\overset{\diagup OH}{\diagdown CH_2R} \qquad \left(\begin{array}{c} R'OH \text{ GIVES} \\ O=C\overset{\diagup OR'}{\diagdown CH_2R} \end{array} \right)$$

KETENE

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Once again, the extension of a carboxylic acid by one C atom is a very useful tactic.

Examples

SUBERIC ACID

ADIPYL CHLORIDE
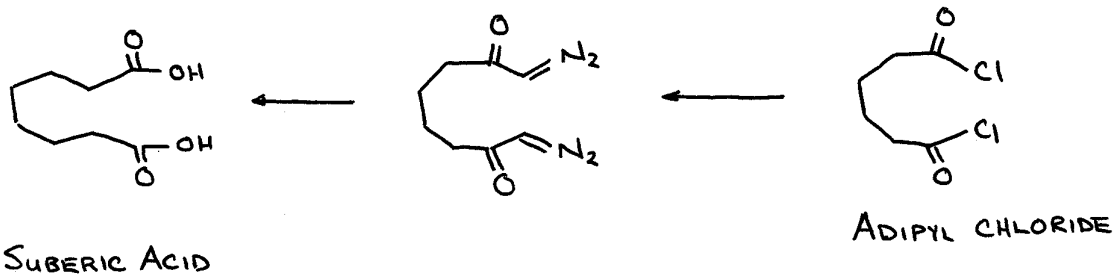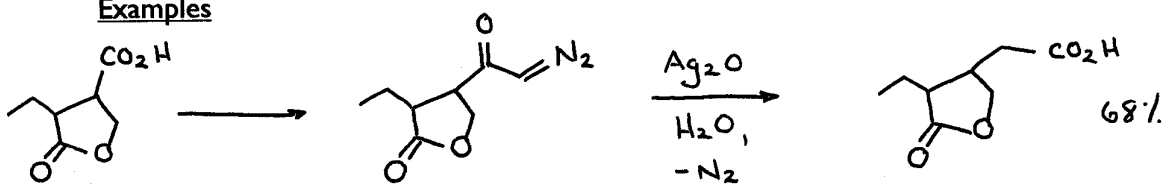
VERY TOLERANT — NO_2, KETONES, LACTONES, ESTERS, OTHER REDUCTION-PRONE FUNCTIONAL GROUPS ALL SURVIVE.