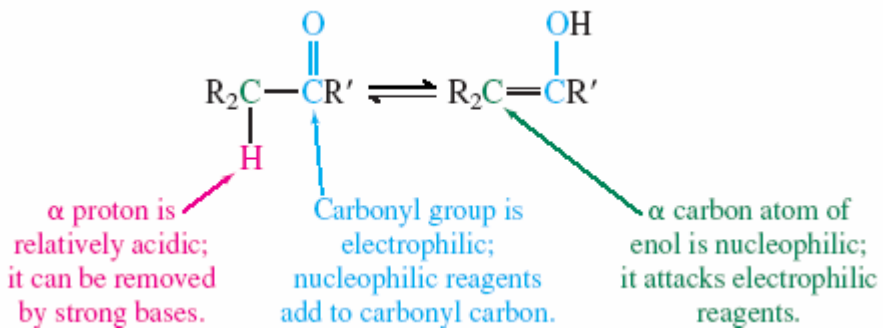
Enols and Enolates

18.15 SUMMARY

Sections 18.1–18.14 Because aldehydes and ketones exist in equilibrium with their corresponding enol isomers, they can express a variety of different kinds of chemical reactivity.



Reactions that proceed via enol or enolate intermediates are summarized in Table 18.2.**Problems**

TABLE 18.1 Reactions of Aldehydes and Ketones That Involve Enol or Enolate Ion Intermediates

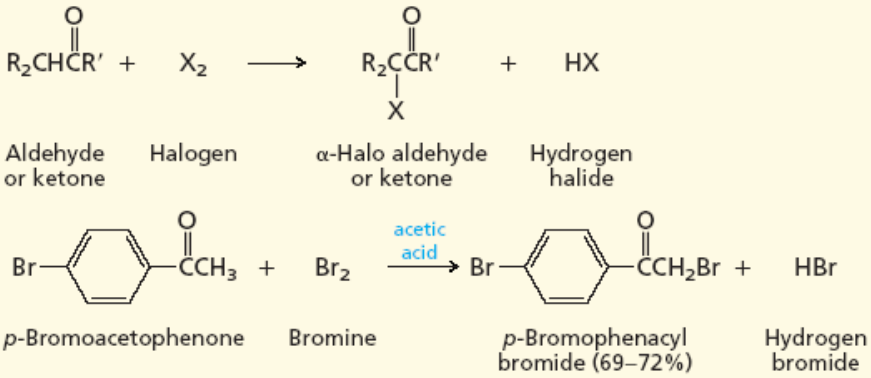
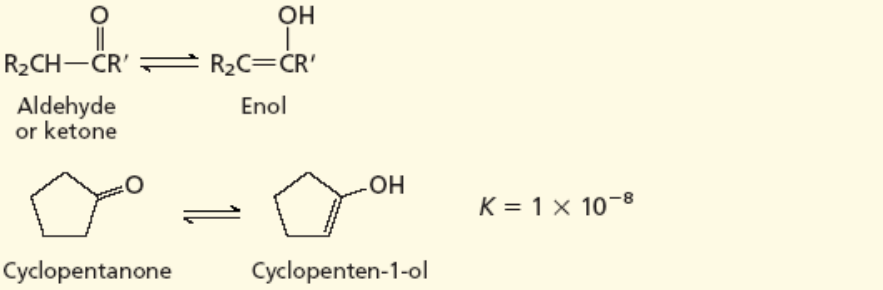
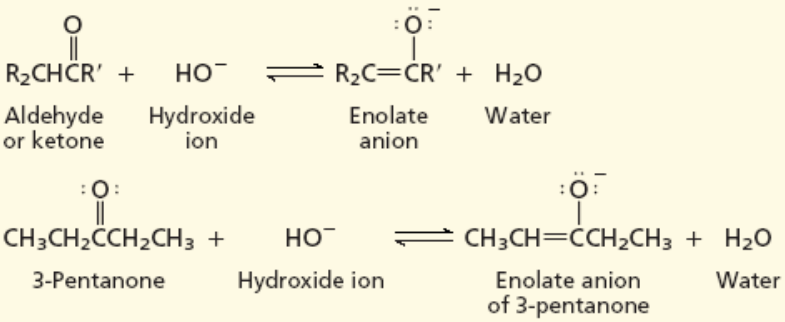
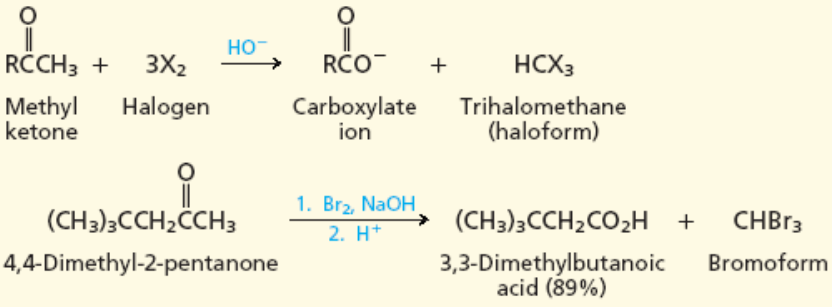
Reaction (section) and comments	General equation and typical example
α Halogenation (Sections 18.2 and 18.3) Halogens react with aldehydes and ketones by substitution; an α hydrogen is replaced by a halogen. Reaction occurs by electrophilic attack of the halogen on the carbon–carbon double bond of the enol form of the aldehyde or ketone. An acid catalyst increases the rate of enolization, which is the rate-determining step.	
Enolization (Sections 18.4 through 18.6) Aldehydes and ketones having at least one α hydrogen exist in equilibrium with their enol forms. The rate at which equilibrium is achieved is increased by acidic or basic catalysts. The enol content of simple aldehydes and ketones is quite small; β-diketones, however, are extensively enolized.	
Enolate ion formation (Section 18.6) An α hydrogen of an aldehyde or a ketone is more acidic than most other protons bound to carbon. Aldehydes and ketones are weak acids, with pK_a's in the 16 to 20 range. Their enhanced acidity is due to the electron-withdrawing effect of the carbonyl group and the resonance stabilization of the enolate anion.	
Haloform reaction (Section 18.7) Methyl ketones are cleaved on reaction with excess halogen in the presence of base. The products are a trihalomethane (haloform) and a carboxylate salt.	

TABLE 18.1 Reactions of Aldehydes and Ketones That Involve Enol or Enolate Ion Intermediates *(Continued)*

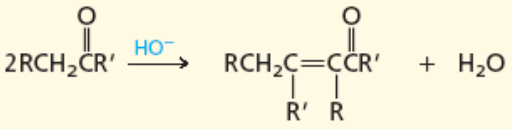
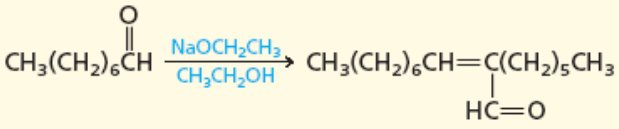
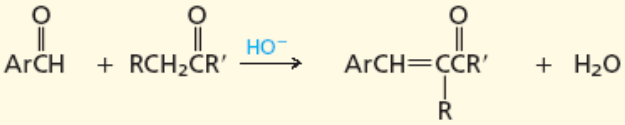
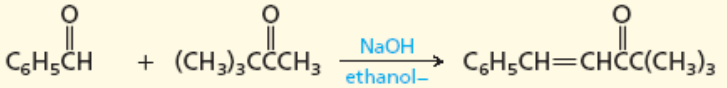
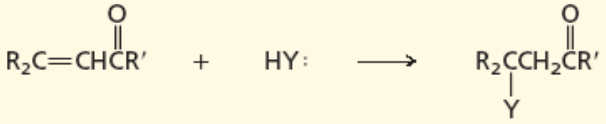
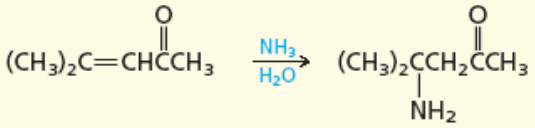
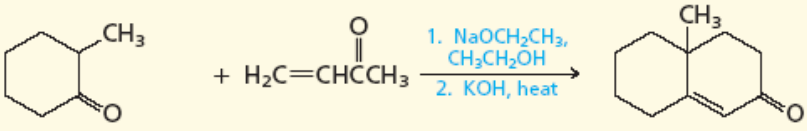
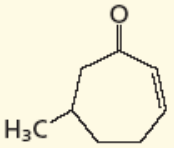
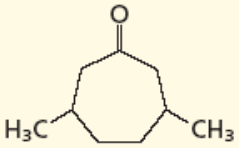
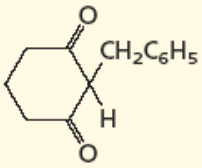
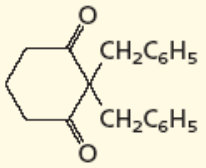
Reaction (section) and comments	General equation and typical example
Aldol condensation (Section 18.9) A reaction of great synthetic value for carbon–carbon bond formation. Nucleophilic addition of an enolate ion to a carbonyl group, followed by dehydration of the β-hydroxy aldehyde, yields an α,β-unsaturated aldehyde.	 Aldehyde — α,β-Unsaturated aldehyde — Water  Octanal — 2-Hexyl-2-decenal (79%)
Claisen–Schmidt reaction (Section 18.10) A mixed aldol condensation in which an aromatic aldehyde reacts with an enolizable aldehyde or ketone.	 Aromatic aldehyde — Aldehyde or ketone — α,β-Unsaturated carbonyl compound — Water  Benzaldehyde — 3,3-Dimethyl-2-butanone — 4,4-Dimethyl-1-phenyl-1-penten-3-one (88–93%)
Conjugate addition to α,β-unsaturated carbonyl compounds (Sections 18.11 through 18.14) The β-carbon atom of an α,β-unsaturated carbonyl compound is electrophilic; nucleophiles, especially weakly basic ones, yield the products of conjugate addition to α,β-unsaturated aldehydes and ketones.	 α,β-Unsaturated aldehyde or ketone — Nucleophile — Product of conjugate addition  4-Methyl-3-penten-2-one (mesityl oxide) — 4-Amino-4-methyl-2-pentanone (63–70%)
Robinson annulation (Section 18.13) A combination of conjugate addition of an enolate anion to an α,β-unsaturated ketone with subsequent intramolecular aldol condensation.	 2-Methylcyclohexanone — Methyl vinyl ketone — 6-Methylbicyclo[4.4.0]-1-decen-3-one (46%)

TABLE 18.1 Reactions of Aldehydes and Ketones That Involve Enol or Enolate Ion Intermediates *(Continued)*

Reaction (section) and comments	General equation and typical example
Conjugate addition of organocopper compounds (Section 18.14) The principal synthetic application of lithium dialkylcuprate reagents is their reaction with α,β-unsaturated carbonyl compounds. Alkylation of the β carbon occurs.	$R_2C{=}CHCR'$ + R''_2CuLi $\xrightarrow[2.\ H_2O]{1.\ \text{diethyl ether}}$ $R_2C(R'')-CH_2CR'$ (O) α,β-Unsaturated aldehyde or ketone; Lithium dialkylcuprate; β-Alkyl aldehyde or ketone  $\xrightarrow[2.\ H_2O]{1.\ LiCu(CH_3)_2}$  6-Methylcyclohept-2-enone; 3,6-Dimethylcycloheptanone (85%)
α Alkylation of aldehydes and ketones (Section 18.15) Alkylation of simple aldehydes and ketones via their enolates is difficult. β-Diketones can be converted quantitatively to their enolate anions, which react efficiently with primary alkyl halides.	$RCCH_2CR$ (O,O) $\xrightarrow{R'CH_2X,\ HO^-}$ $RCCHCR$ (O,O; CH_2R') β-Diketone; α-Alkyl-β-diketone  + $C_6H_5CH_2Cl$ $\xrightarrow[\text{ethanol}]{KOCH_2CH_3}$  2-Benzyl-1,3-cyclohexanedione; Benzyl chloride; 2,2-Dibenzyl-1,3-cyclohexanedione (69%)