Reactions of monosaccharides

α-Hydrogen Reaction

Epimerization

Enediol Rearrangement

Carbonyl reactions:

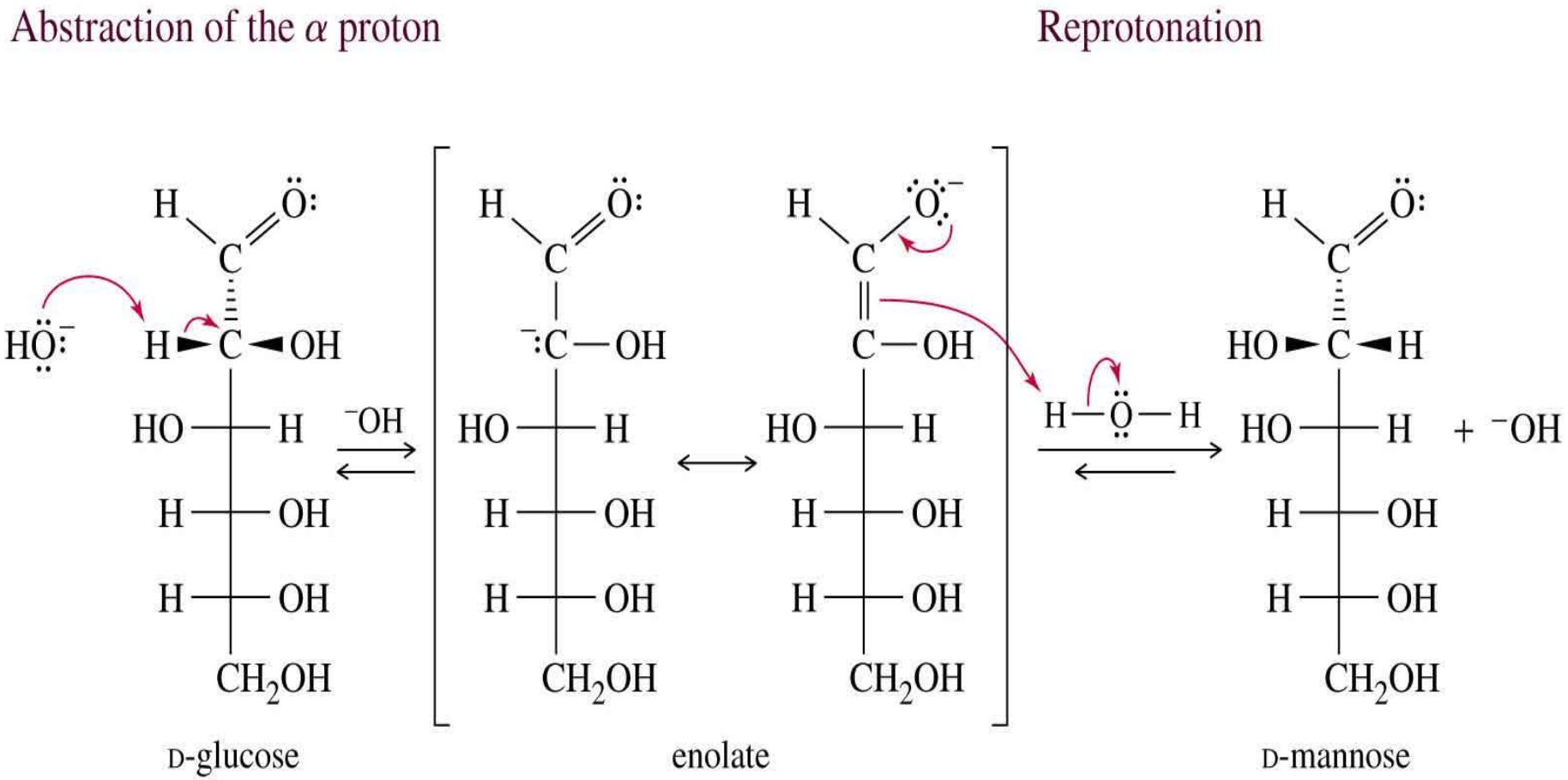
- Osazone formation
- Cyanohydrin reaction
- Reduction
- Oxidation
- Action of base
- Action of acid
- Ring chain tautomerism

Alcohol reactions

- Glycoside formation
- Ether formation
- Ester formation

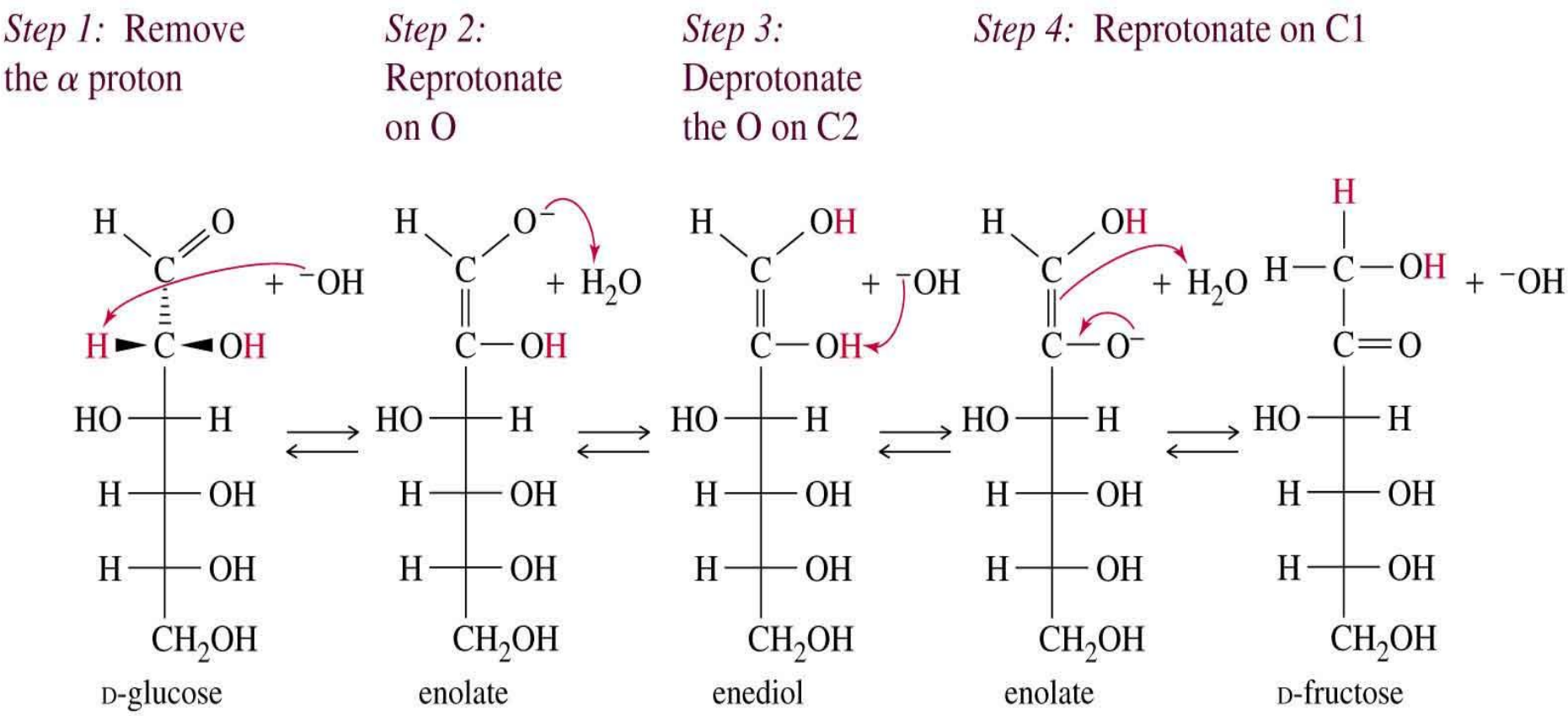
Epimerization

In base, H on C2 may be removed to form enolate ion.
Reprotonation may change the stereochemistry of C2.



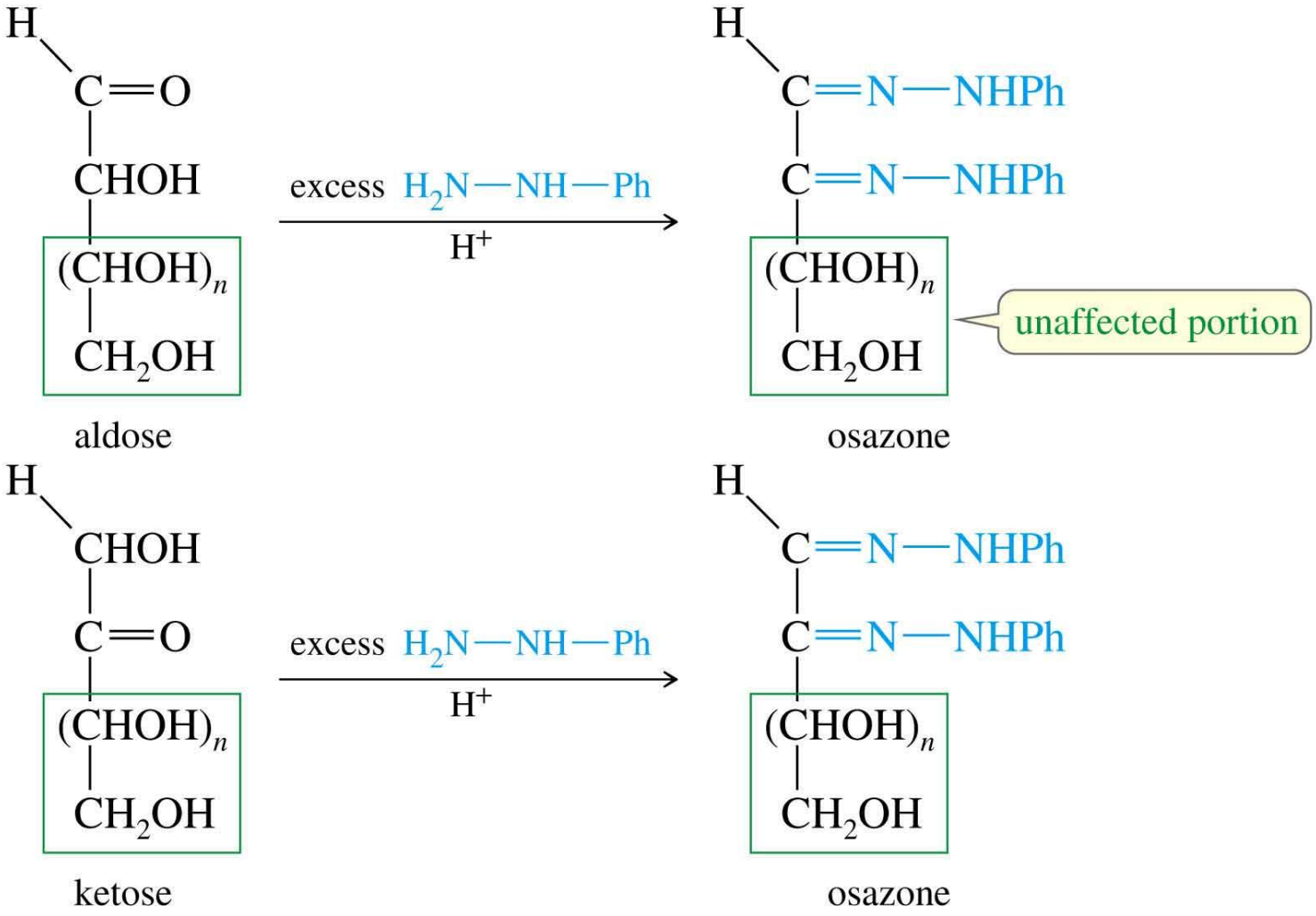
Enediol Rearrangement

In base, the position of the C=O can shift. Chemists use acidic or neutral solutions of sugars to preserve their identity.

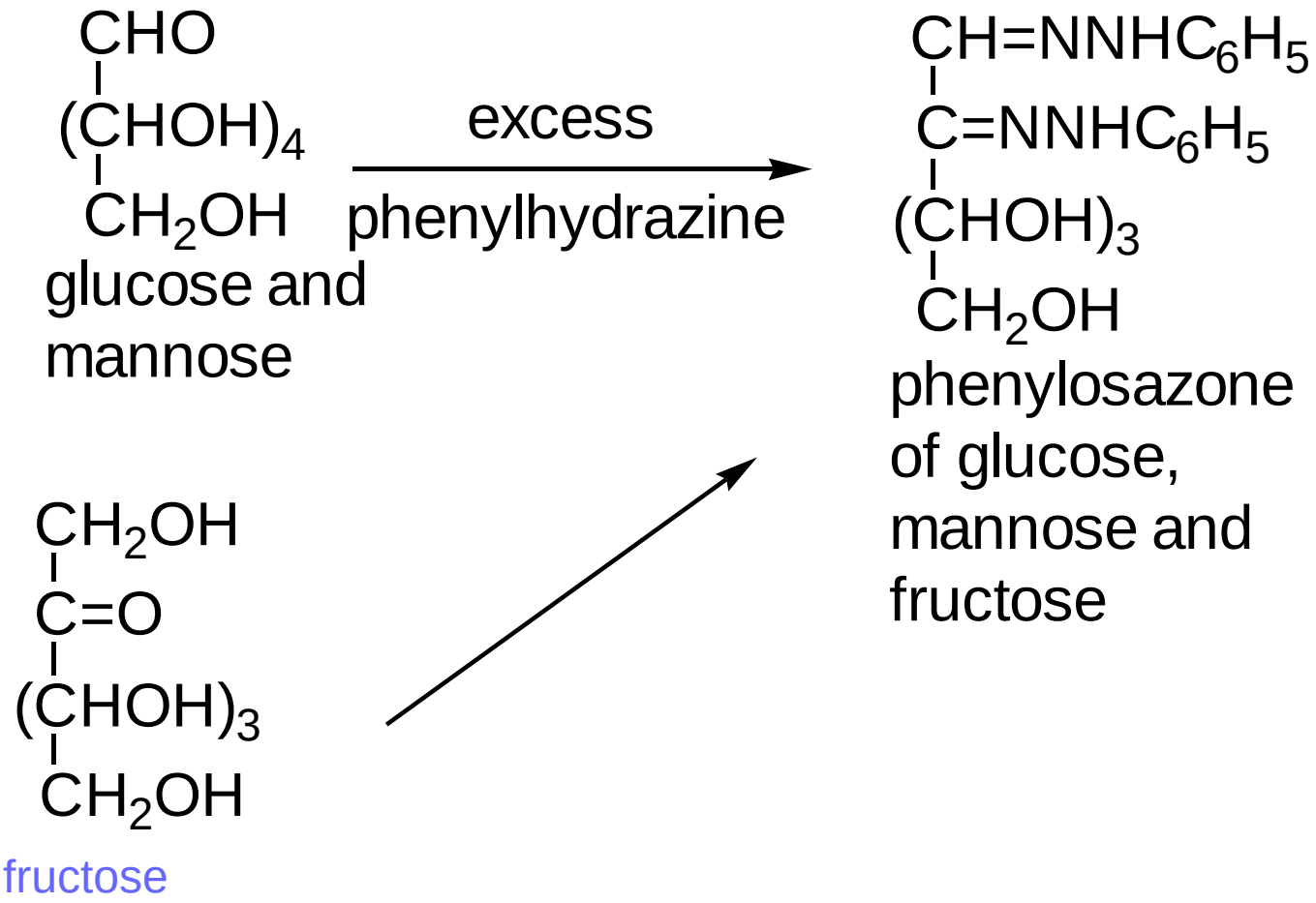


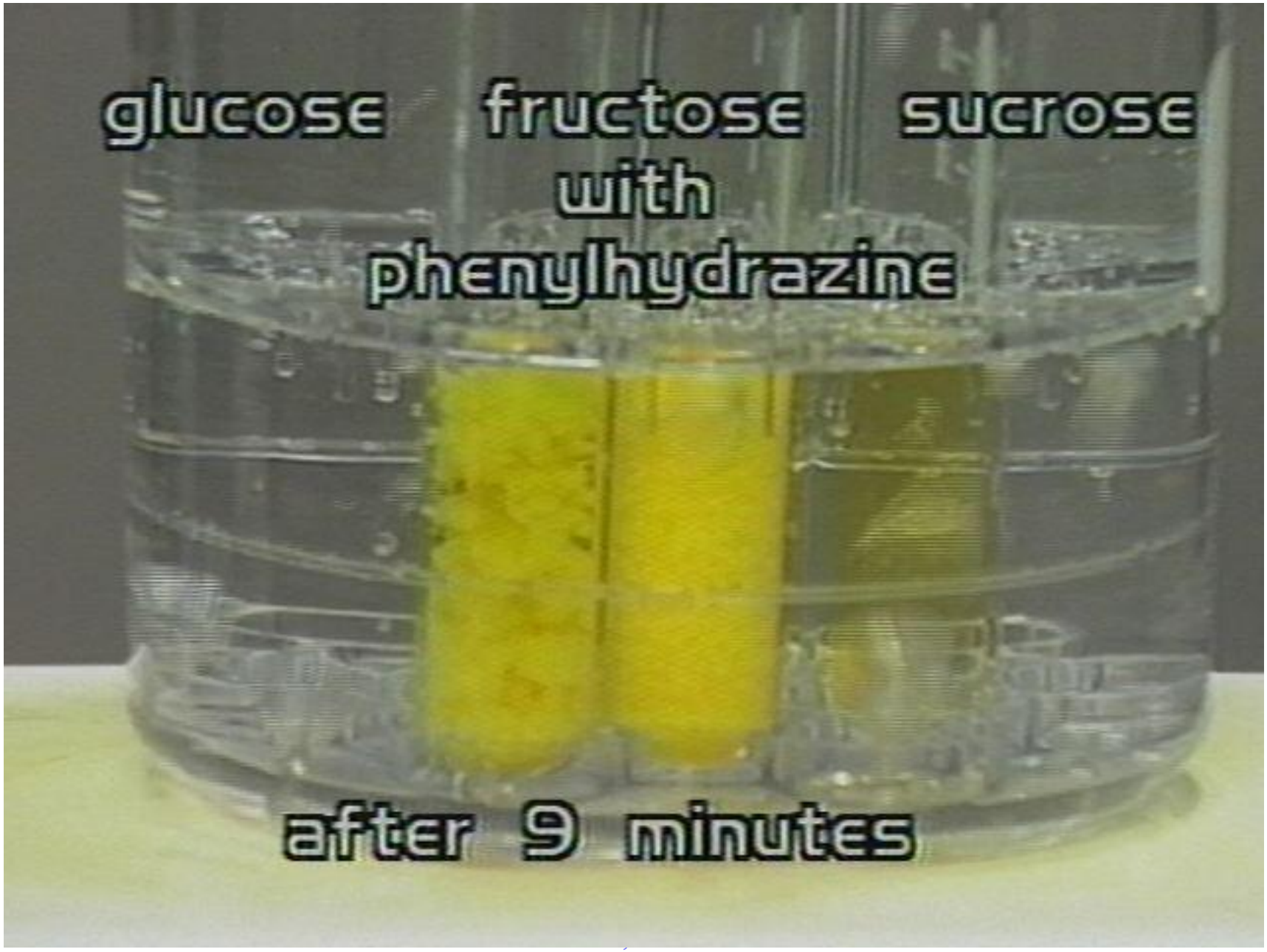
Osazone Formation

Both C1 and C2 react with phenylhydrazine.



Osazones


CHO
(CHOH)4
CH2OH
excess
phenylhydrazine
glucose and
mannose
CH=NNHC6H5
C=NNHC6H5
(CHOH)3
CH2OH
phenylosazone
of glucose,
mannose and
fructose
CH2OH
C=O
(CHOH)3
CH2OH
fructose


glucose fructose sucrose
with
phenylhydrazine
after 9 minutes

Reduction of Simple Sugars

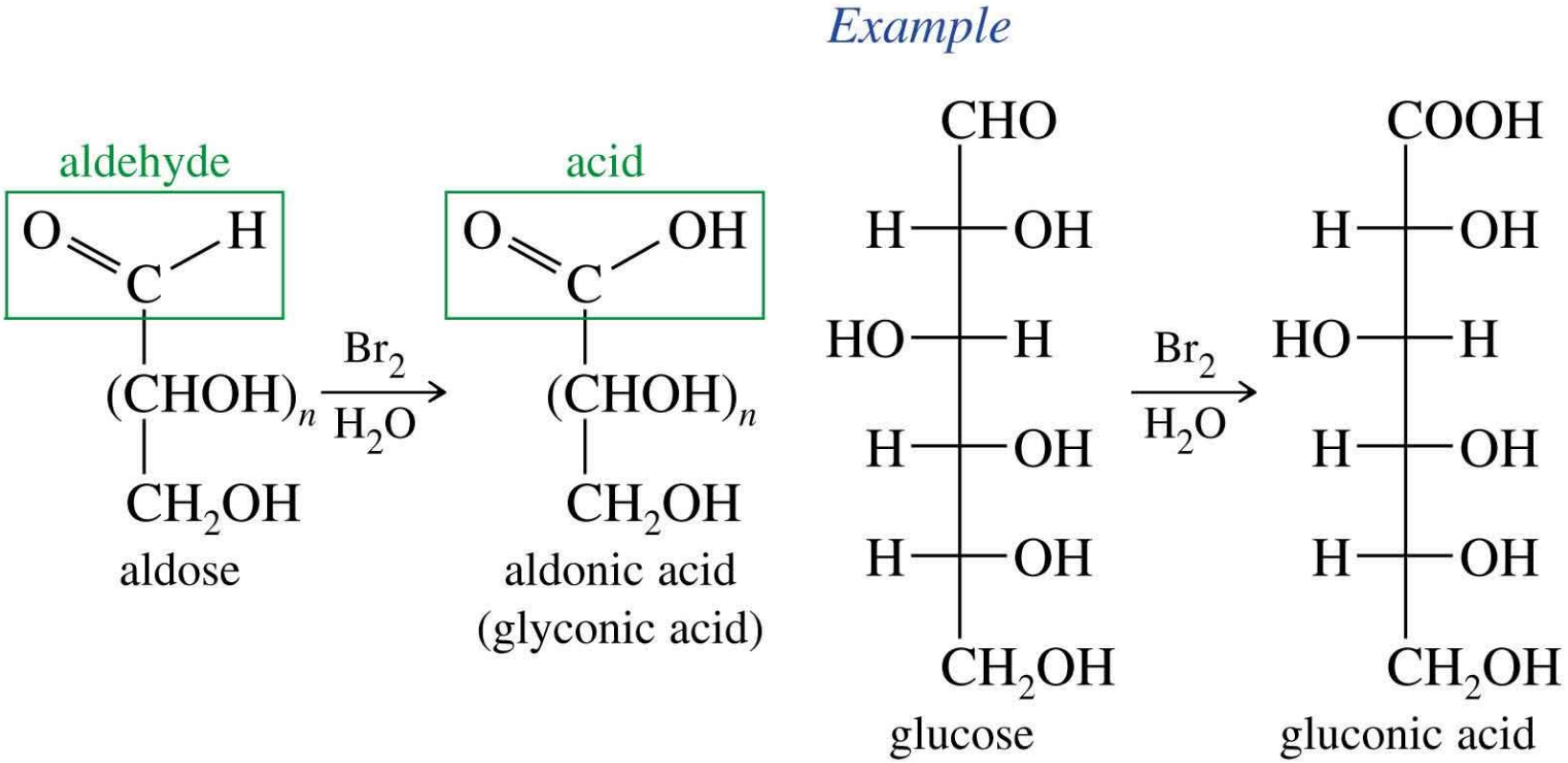
- C=O of aldoses or ketoses can be reduced to C-OH by $NaBH_4$ or H_2/Ni.

- Name the sugar alcohol by adding *-itol* to the root name of the sugar.

- Reduction of D-glucose produces D-glucitol.
- Reduction of D-fructose produces a mixture of D-glucitol and D-mannitol.

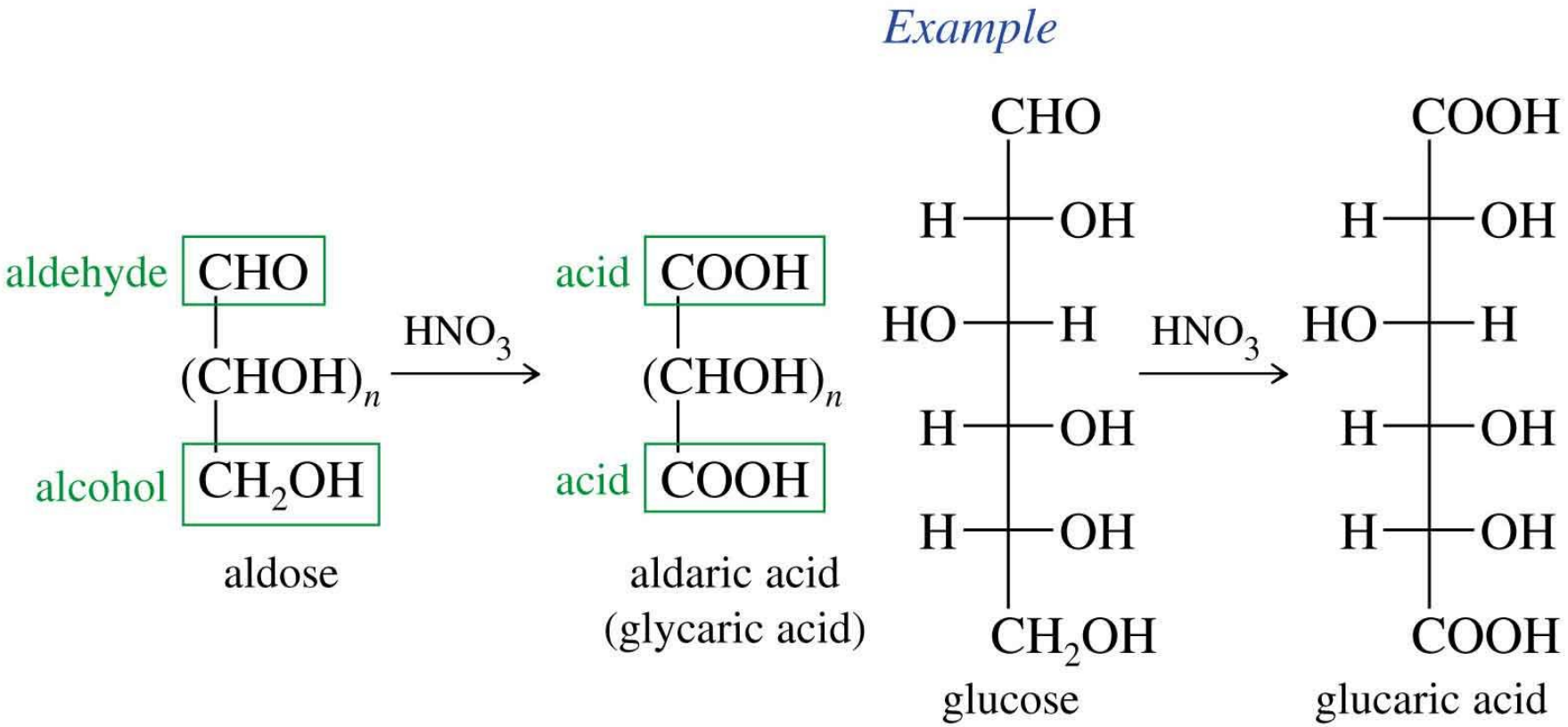
Oxidation by Bromine

Bromine water oxidizes aldehyde, but not ketone or alcohol; forms aldonic acid.



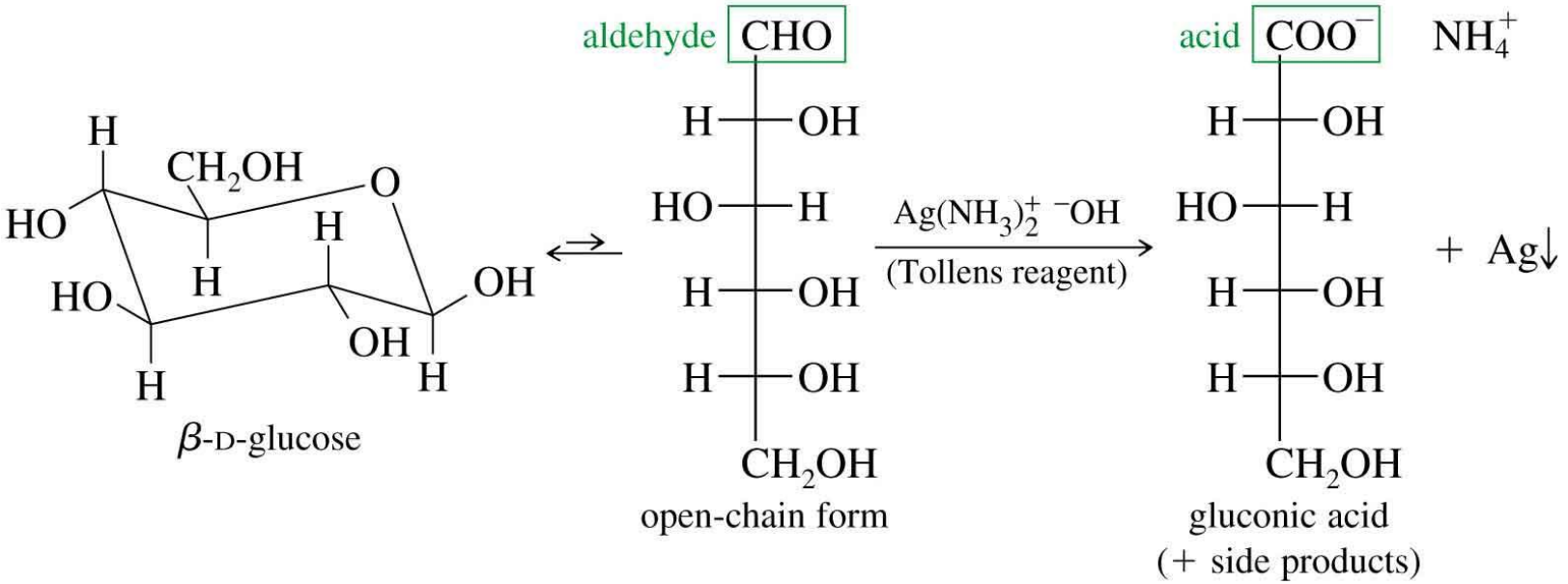
Oxidation by Nitric Acid

Nitric acid oxidizes the aldehyde and the terminal alcohol; forms aldaric acid.



Oxidation by Tollens Reagent

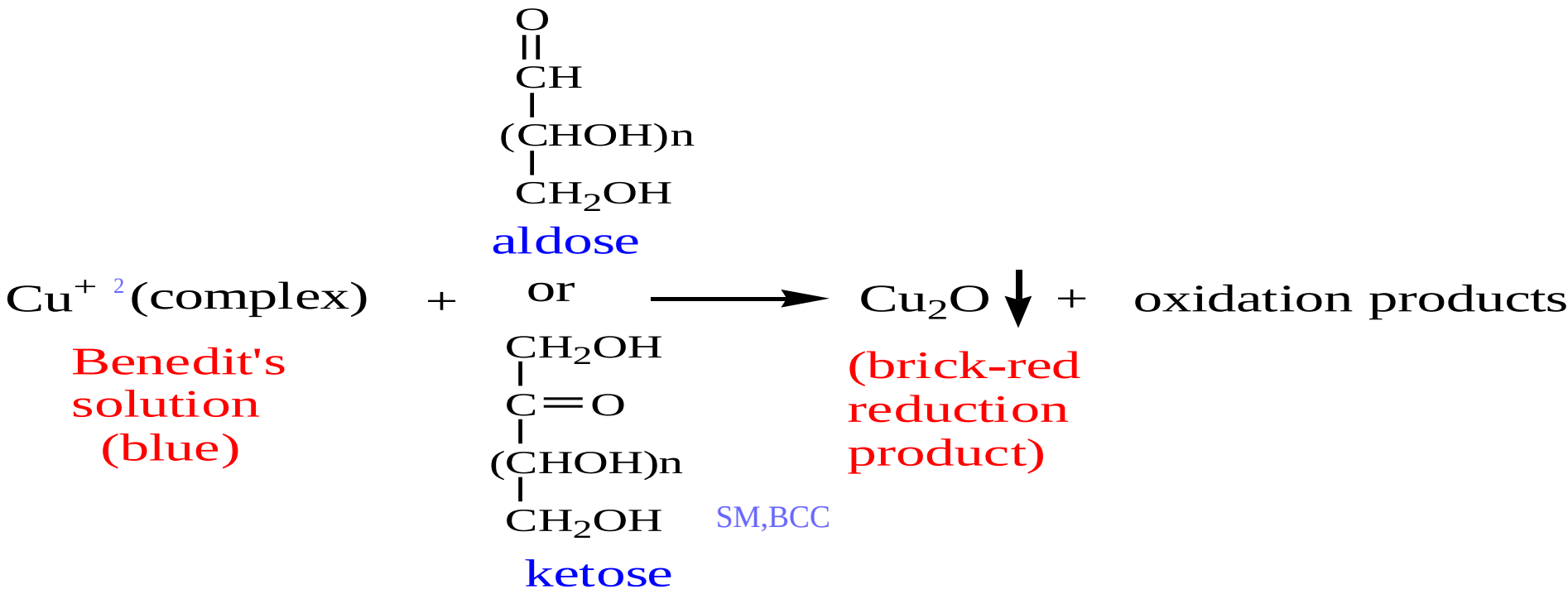
- Tollens reagent reacts with aldehyde, but the base promotes enediol rearrangements, so ketoses react too.
- Sugars that give a silver mirror with Tollens are called reducing sugars.



BENEDICT'S OR TOLLENS' REAGENTS: REDUCING SUGARS

Sugars that give positive tests with Tollens'or Benedict's solutions are known as reducing sugars, and all carbohydrates that contain a hemiacetal group or a hemoketal group give positive tests.

Carbohydrates that contain only acetal or ketal group do not give positive tests with Tollens'or Benedict's solution.

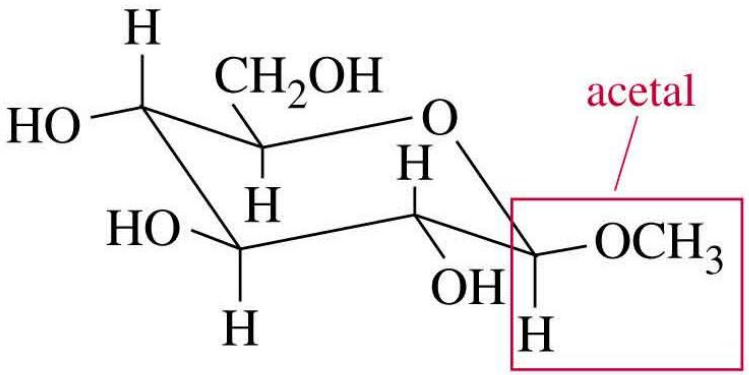


SM,BCC

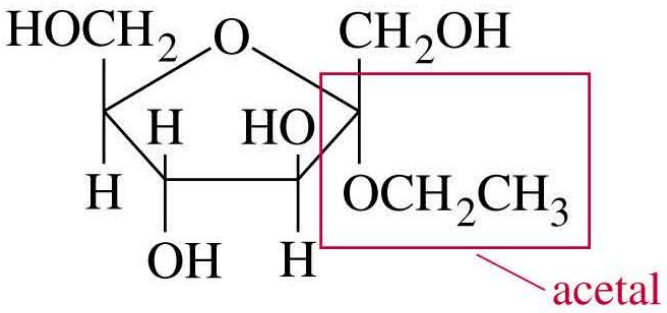
Nonreducing Sugars

- Glycosides are acetals, stable in base, so they do not react with Tollens reagent.
- Disaccharides and polysaccharides are also acetals, nonreducing sugars.

Examples of nonreducing sugars



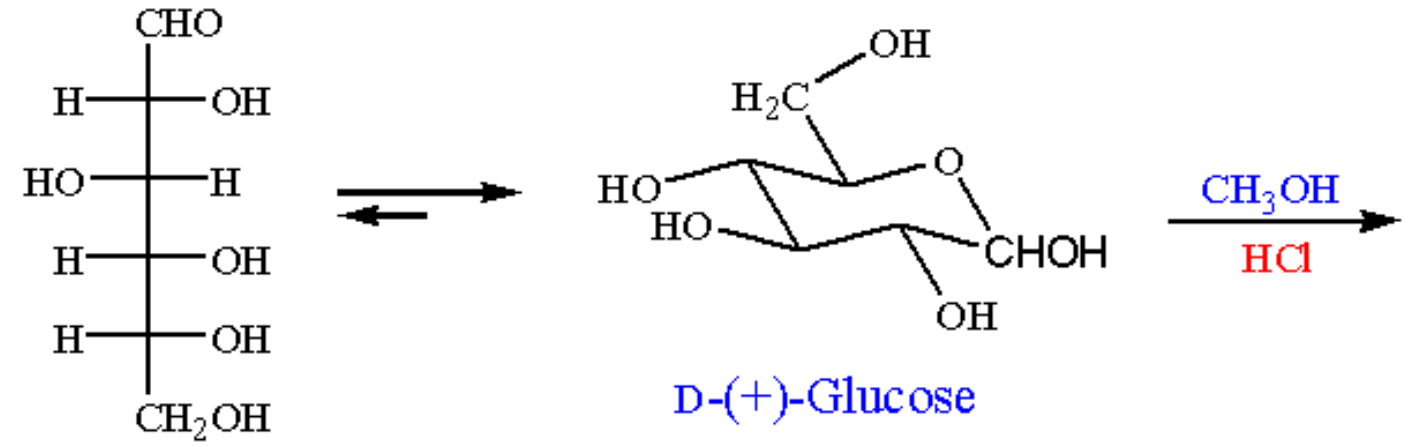
methyl β-D-glucopyranoside
(or methyl β-D-glucoside)



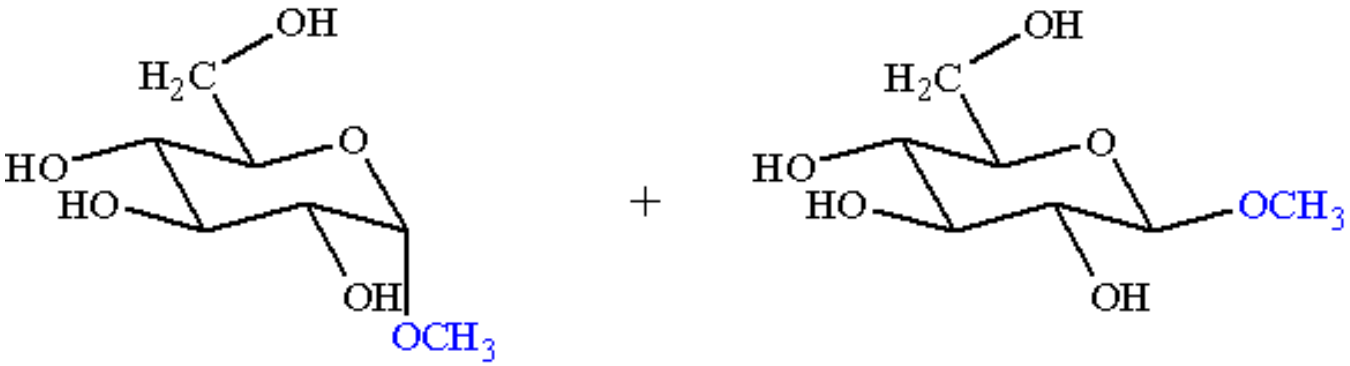
ethyl α-D-fructofuranoside
(or ethyl α-D-fructoside)

GLYCOSIDE FORMATION

When a small amount of gaseous hydrogen chloride is passed into a solution of D-(+)-glucose in methanol, the reaction as follows:



D-(+)-Glucose



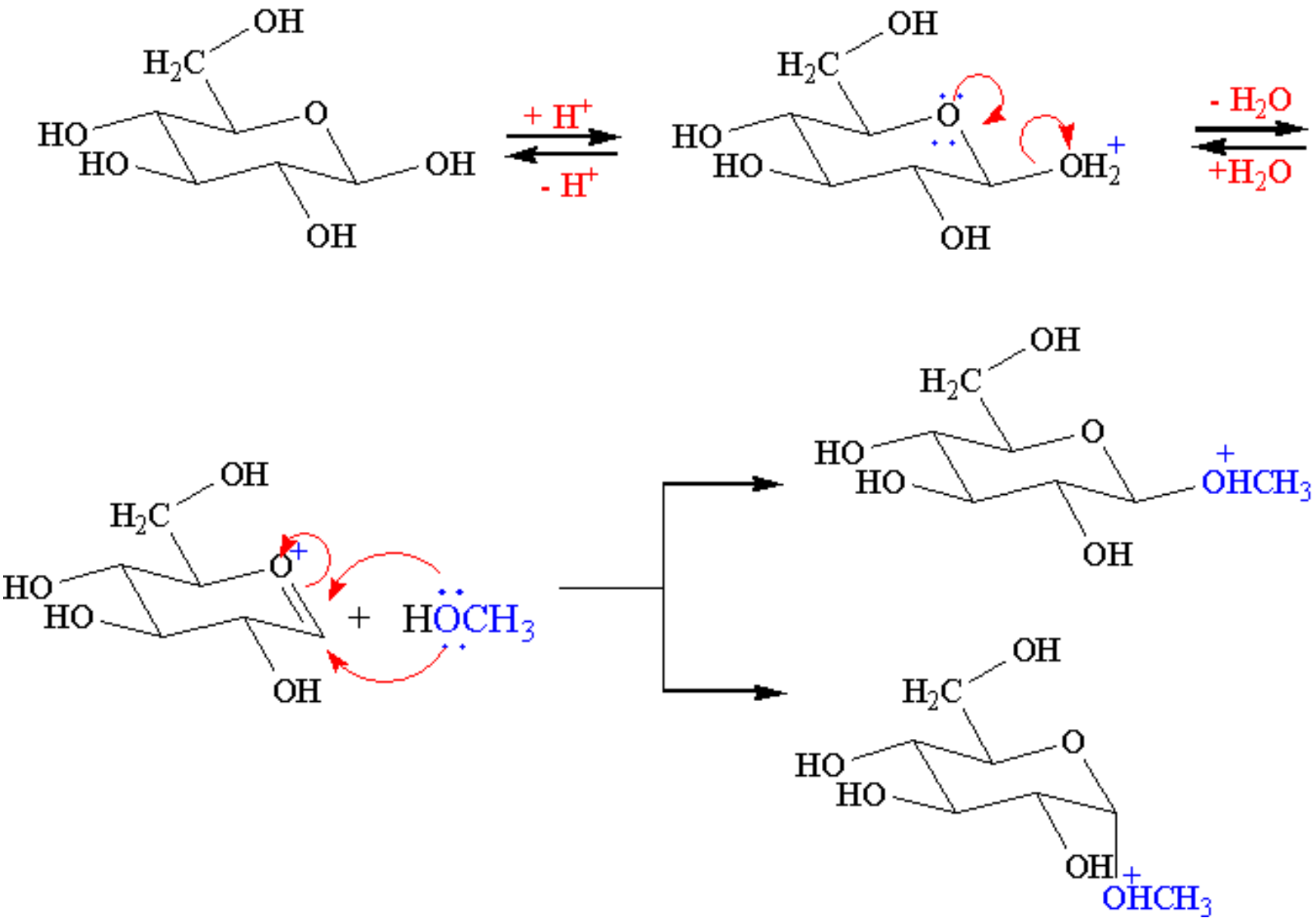
methyl D-Glucopyranose

(mp, 165 $[a]_D^{25} = +158^0$)

methyl D-Glucopyranose

(mp, 107 $[a]_D^{25} = -33^0$)

The mechanism for the formation of the methyl glucosides



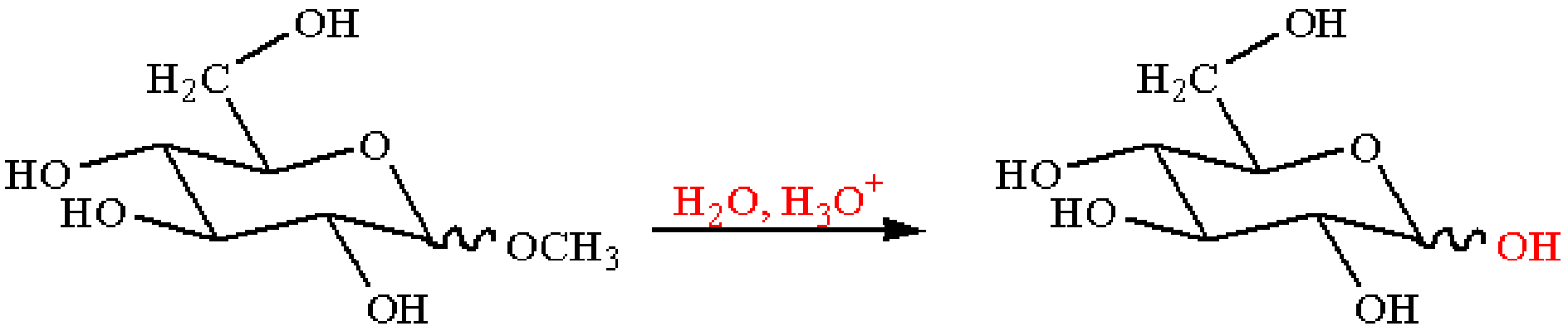
Carbohydrate acetals, generally, are called glycosides. Foe example:

acetal of glucose → glucoside

acetals of mannose → mannosides

ketals of fructose → fructosides

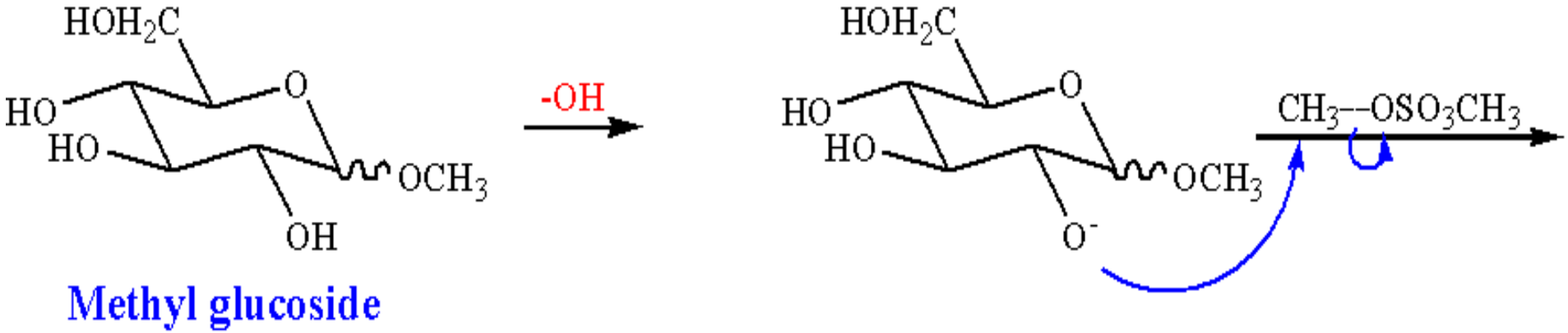
In acidic solutions, however, glycosides undergo hydrolysis to produce a sugar and alcohol:



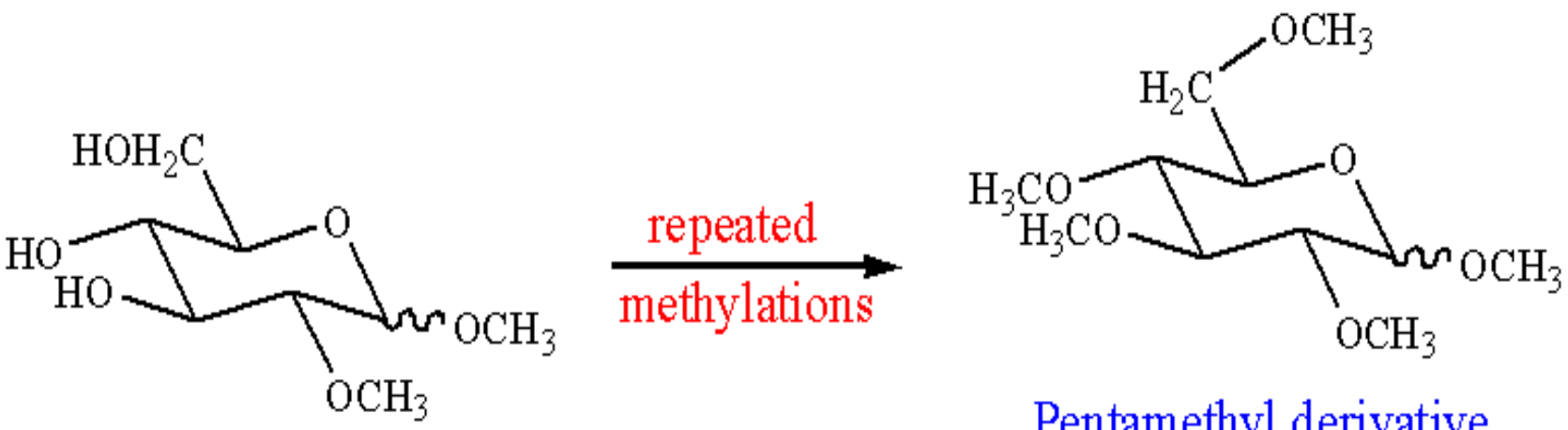
Glycoside **Sugar**

ETHERS FORMATION

A methyl glucoside can be converted to the derivative by treating it with excess dimethyl sulfate in aqueous sodium hydroxide.



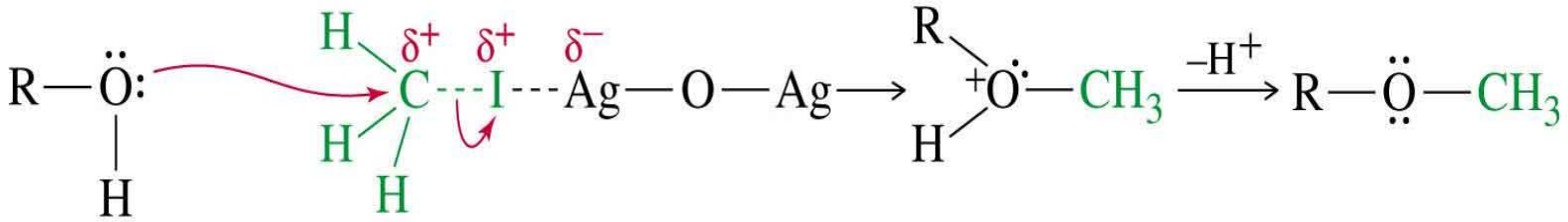
Methyl glucoside



Pentamethyl derivative

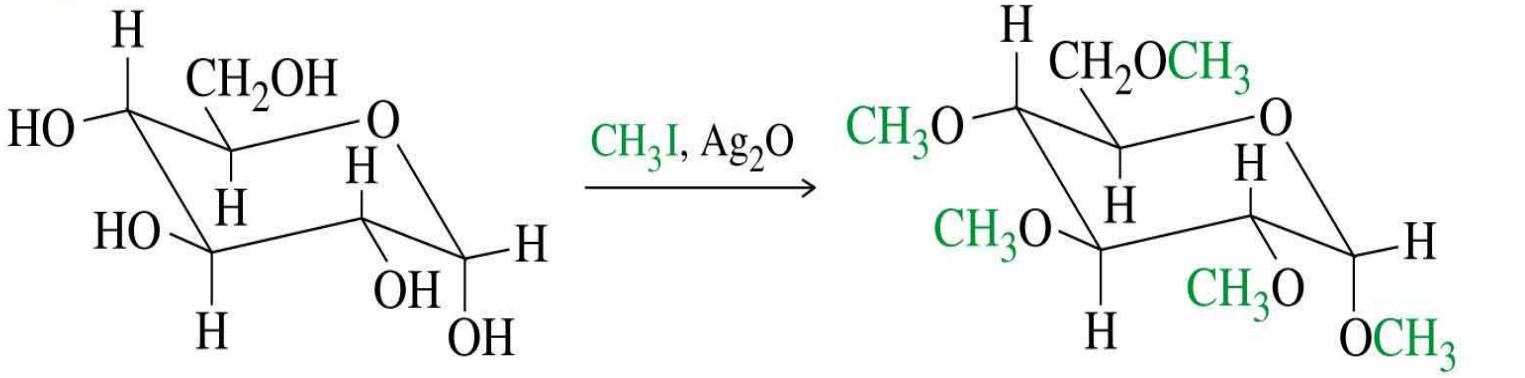
ETHERS FORMATION

- Convert all -OH groups to -OR, using a modified Williamson synthesis, after converting sugar to acetal, stable in base.



sugar hydroxyl group | polarized CH_3I | ether

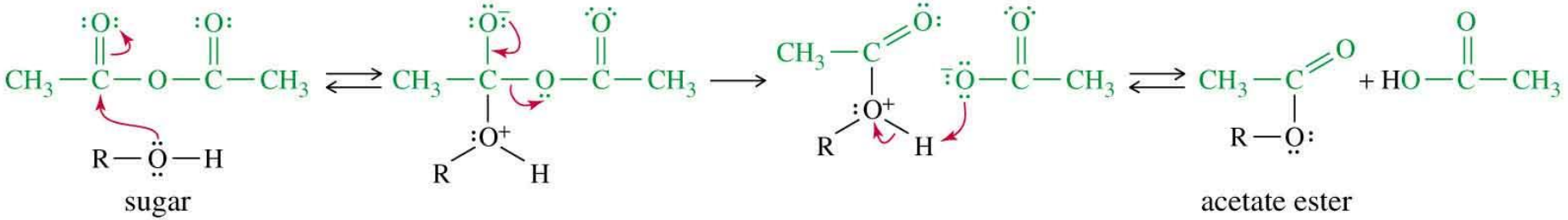
Example



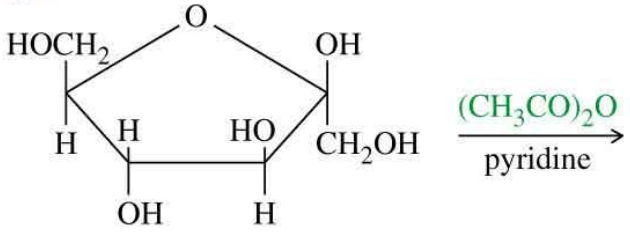
α-D-glucopyranose | methyl 2,3,4,6-tetra-*O*-methyl-α-D-glucopyranoside

Ester Formation

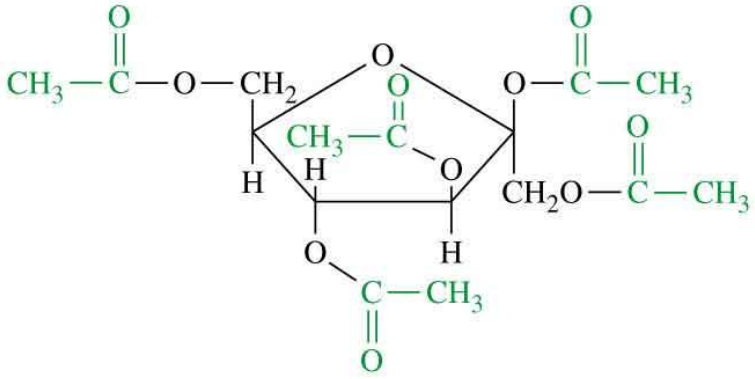
Acetic anhydride with pyridine catalyst converts all the oxygens to acetate esters.



Example



$(CH_3CO)_2O$
pyridine



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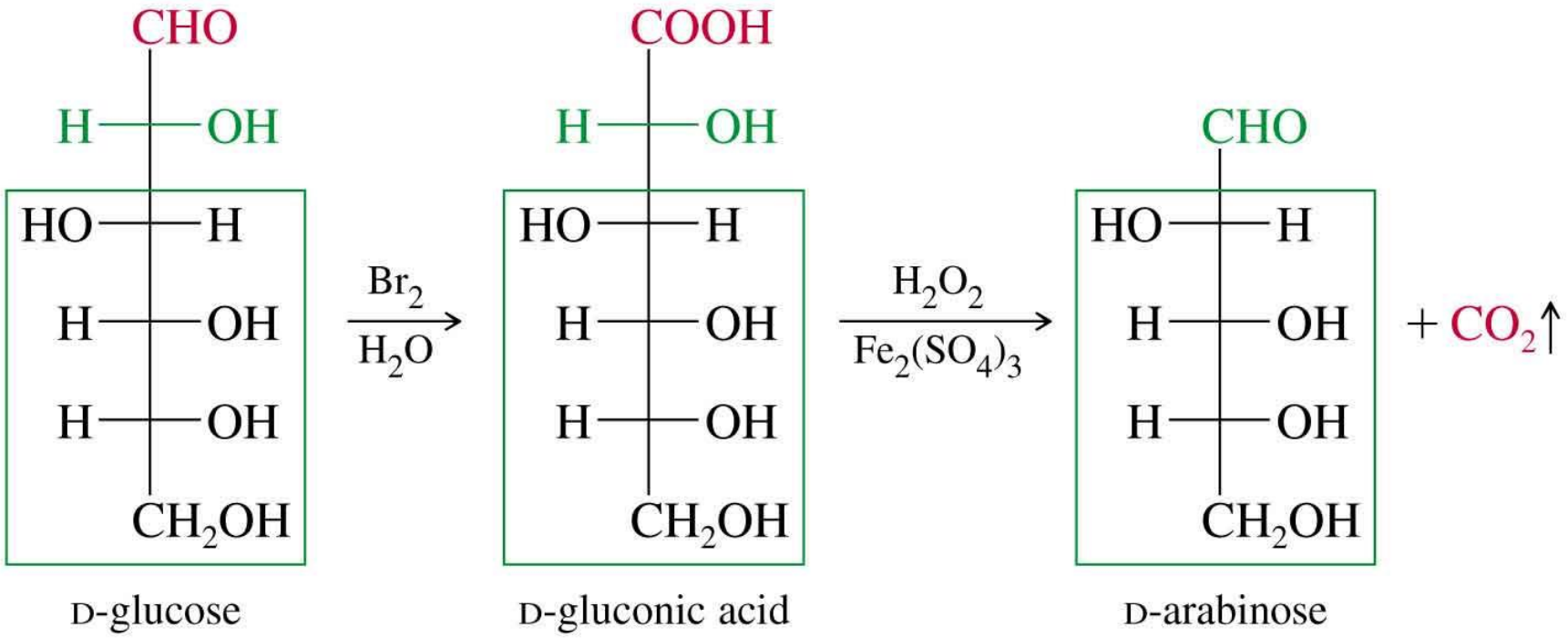
Ruff Degradation

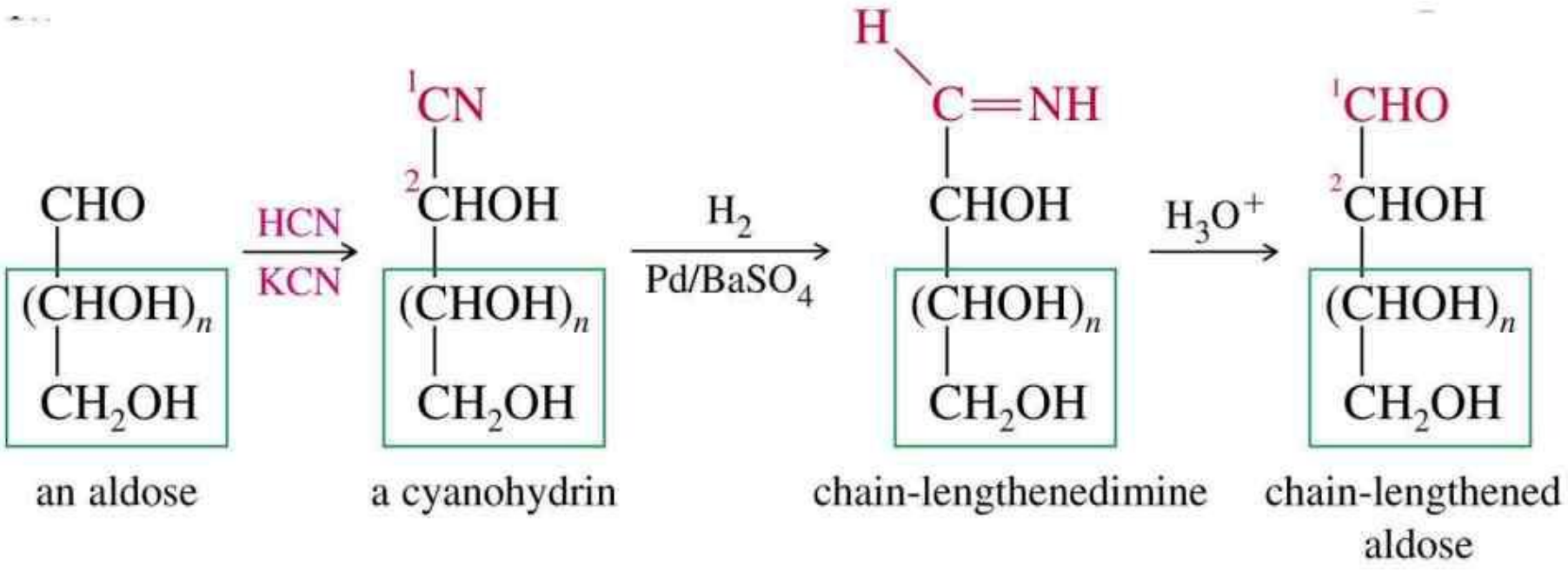
Aldose chain is shortened by oxidizing the aldehyde to -COOH, then decarboxylation.



D-glucose D-gluconic acid D-arabinose

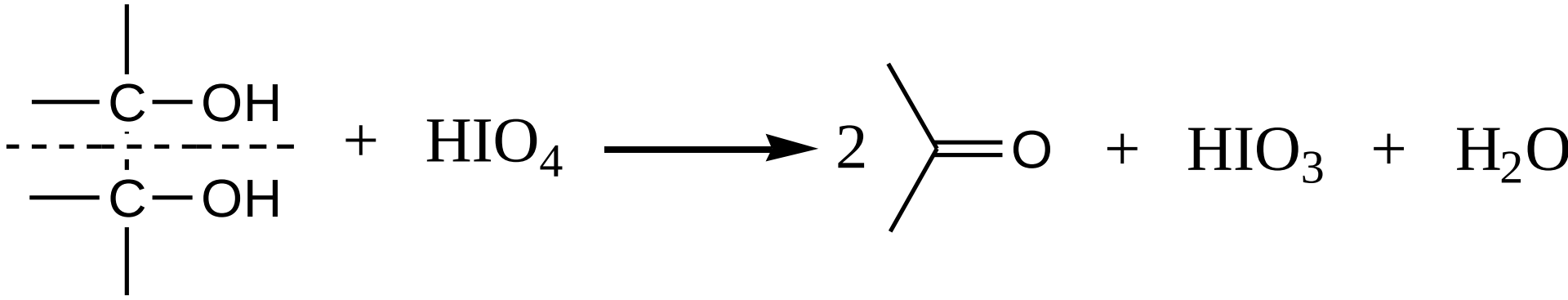
Kiliani-Fischer Synthesis

- This process lengthens the aldose chain.
- A mixture of C2 epimers is formed.



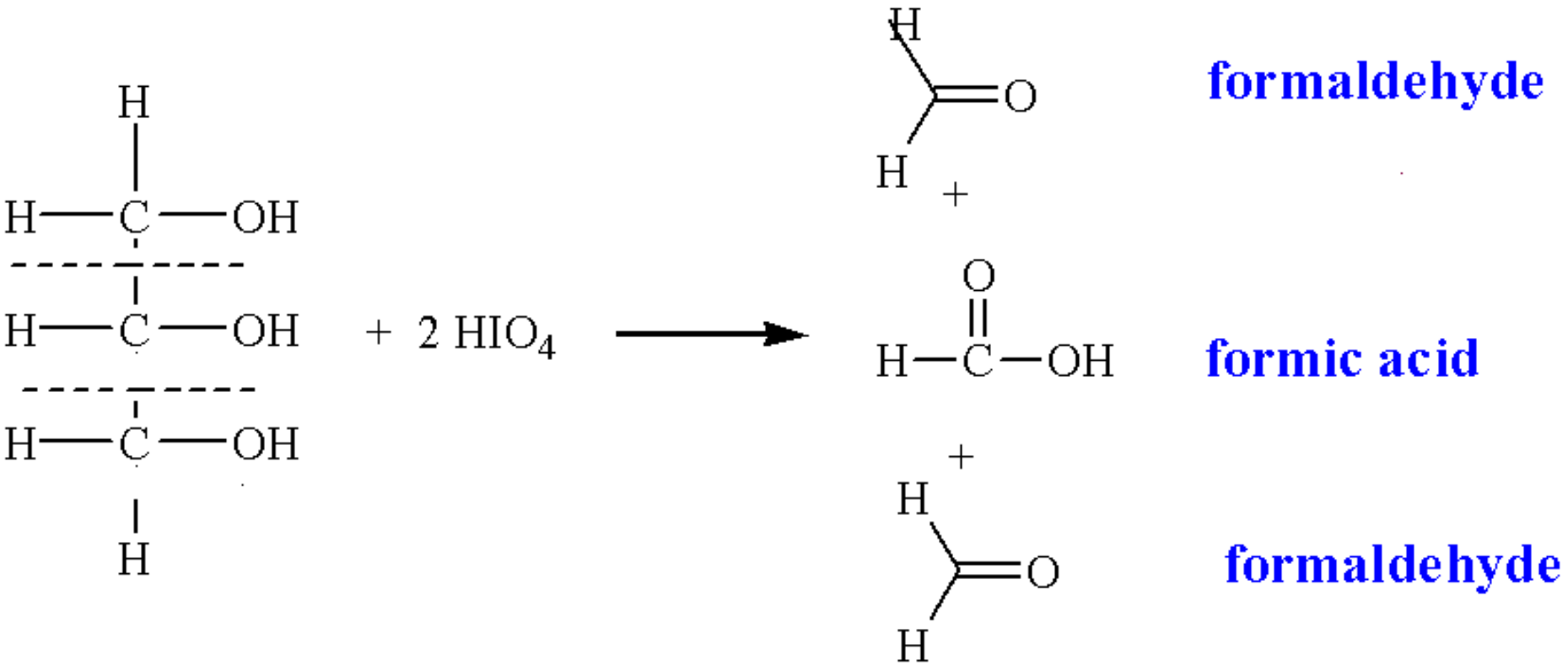
PERIODATE OXIDATIONS

- Compounds that have hydroxyl groups on adjacent atoms undergo oxidative cleavage when they are treated with aqueous periodic acid.
- Carbon-carbon bonds breaks and carbonyl compounds produced.
- This reaction usually takes place in quantitative yield.



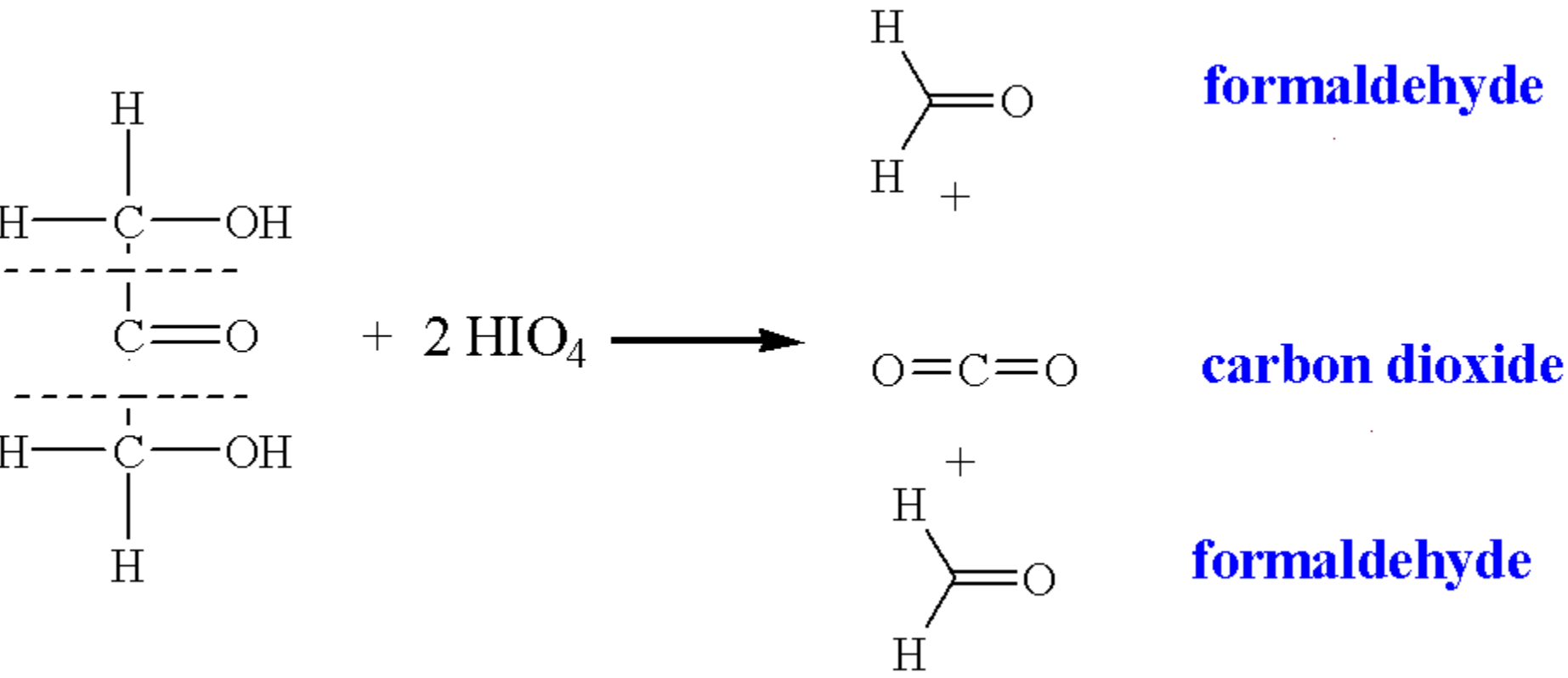
PERIODATE OXIDATIONS

Three –CHOH groups : gives one molar equivalent of formic acid and two equivalents of formaldehyde.



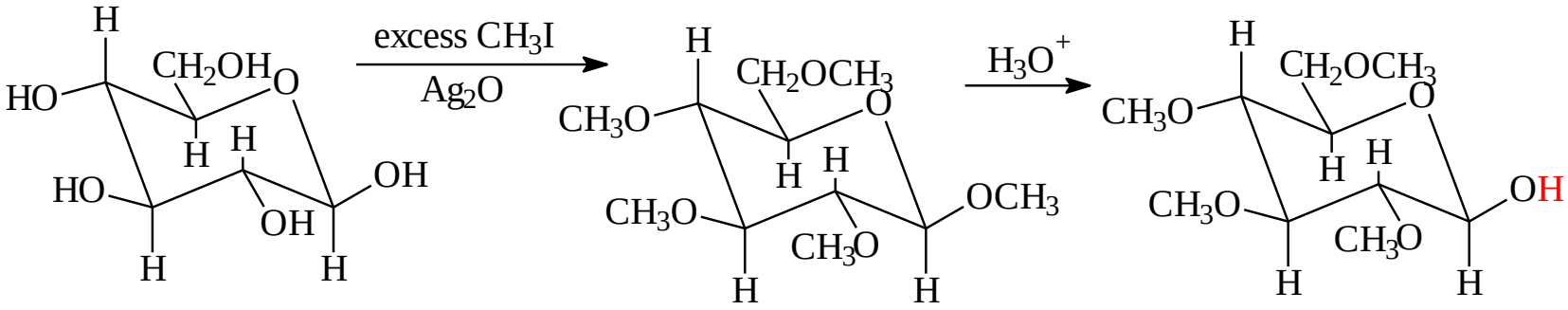
PERIODATE OXIDATIONS

- Periodic acid dose not cleave compounds in which the hydroxyl groups are separated by an intervening –CH**2** group, nor those in which a hydroxyl group is adiacent to an ether or acetal function.



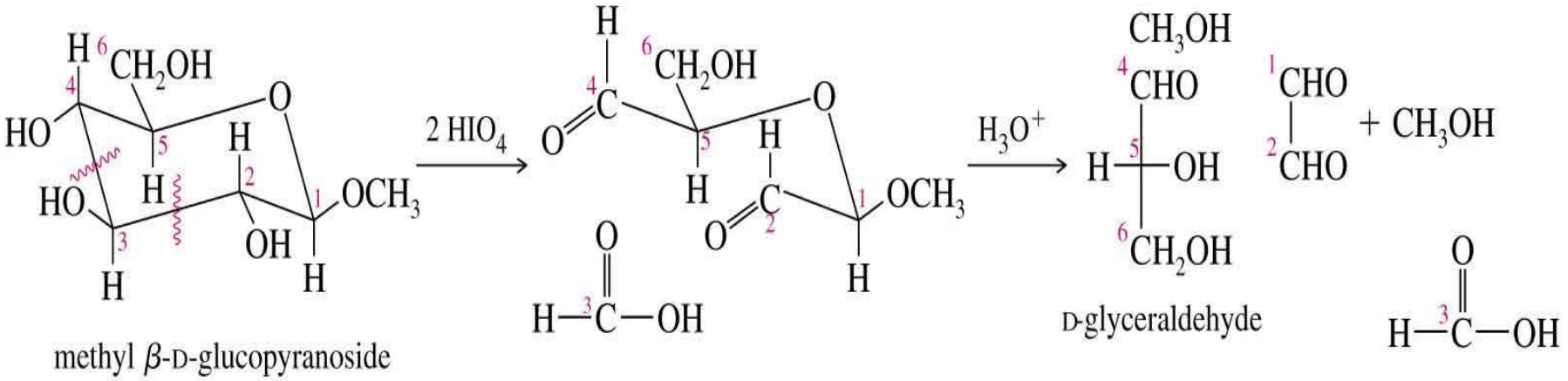
Determination of Ring Size

- Haworth determined the pyranose structure of glucose in 1926.
- The anomeric carbon can be found by methylation of the -OH's, then hydrolysis.



Periodic Acid Cleavage

- Periodic acid cleaves vicinal diols to give two carbonyl compounds.
- Separation and identification of the products determine the size of the ring.



methyl β-D-glucopyranoside

D-glyceraldehyde