Leah4Sci presents:

Cheat Sheet Collection

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-clickable links-

MCAT

ORGO

MCAT MATH

MCAT CHEAT SHEET STUDY GUIDE

Complete Math without a calculator video series:

Leah4sci.com/MCATMath

Must-know Multiplication Table

	1	2	3	4	5	6	7	8	9	10	11	12	15	25	50
1	1	2	3	4	5	6	7	8	9	10	11	12	15	25	50
2	2	4	6	8	10	12	14	16	18	20	22	24	30	50	100
3	3	6	9	12	15	18	21	24	27	30	33	36	45	75	150
4	4	8	12	16	20	24	28	32	36	40	44	48	60	100	200
5	5	10	15	20	25	30	35	40	45	50	55	60	75	125	250
6	6	12	18	24	30	36	42	48	54	60	66	72	90	150	300
7	7	14	21	28	35	42	49	56	63	70	77	84	105	175	350
8	8	16	24	32	40	48	56	64	72	80	88	96	120	200	400
9	9	18	27	36	45	54	63	72	81	90	99	108	135	225	425
10	10	20	30	40	50	60	70	80	90	100	110	120	150	250	500
11	11	22	33	44	55	66	77	88	99	110	121	132	165	275	550
12	12	24	36	48	60	72	84	96	108	120	132	144	180	300	600

Must-know conversion Values

Tutorial video #6 → LEAH4SCI.COM/MCATMATH

Fraction	$\frac{1}{1}$	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{4}$	$\frac{1}{5}$	$\frac{1}{6}$	$\frac{1}{7}$	$\frac{1}{8}$	$\frac{1}{9}$	$\frac{1}{10}$	$\frac{1}{11}$	$\frac{1}{12}$
Decimal → Calc	1	0.5	0.33	0.25	0.2	0.167	0.142	0.125	0.111	0.1	0.091	0.083
* MCAT	1	0.5	0.33	0.25	0.2	0.17	0.14	0.13	0.11	0.1	0.09	0.08
Percent	100%	50%	33%	25%	20%	17%	14%	13%	11%	10%	9%	8%

Squares

Tutorial video #5 → LEAH4SCI.COM/MCATMATH

$1^2=1$ $2^2=4$ $3^2=9$ $4^2=16$ $5^2=25$ $6^2=36$ $7^2=49$

$8^2=64$ $9^2=81$ $10^2=100$ $11^2=121$ $12^2=144$ $15^2=225$ $25^2=625$

Scientific Notation

Tutorial video #4 → LEAH4SCI.COM/MCATMATH

$6300. \rightarrow 6.3 \times 10^{3}$ (from ↩ side)

$0.0045 \rightarrow 4.5 \times 10^{-3}$ (from ↪ side)

Exponent Calculations

Tutorial video 4/5 → LEAH4SCI.COM/MCATMATH

$\sqrt{X} = X^{1/2}$ $\sqrt[3]{X} = X^{1/3}$

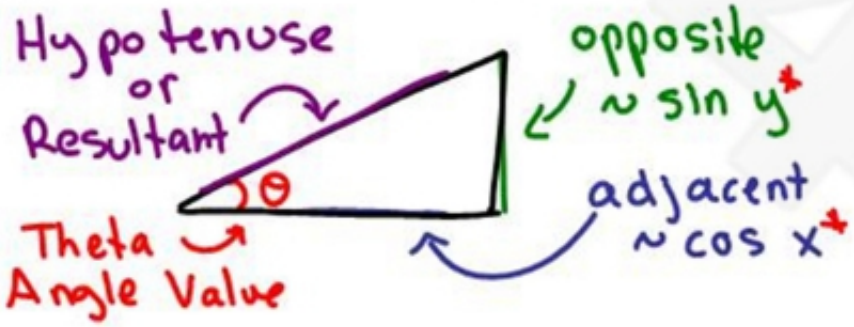
$(X^2)(X^3) = (X \cdot X)^{(2+3)}$ X^5 $(X^2)^3 = X^{(2 \cdot 3)} = X^6$

$(A \times 10^3)(B \times 10^2) = (A \cdot B) \times 10^{3+2} = AB \times 10^5$

$(A \times 10^9) \div (B \times 10^3) = (A \div B) \times 10^{9-3} = \frac{A}{B} \times 10^6$

Trigonometry

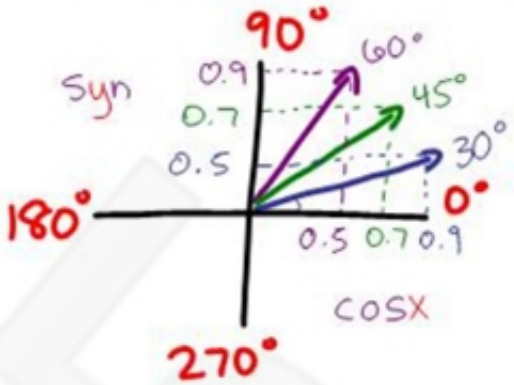
Tutorial video #7 → LEAH4SCI.COM/MCATMATH



SOHCAHTOA

$\sin = \frac{opp}{hyp} = Y$ $\cos = \frac{adj}{hyp} = X$ $\tan = \frac{opp}{adj} = \frac{Y}{X}$

* cos usually x, sin usually y, few times reverse



		0°	30°	45°	60°	90°	180°
* cos	Calculator	1	0.866	0.707	0.5	0	-1
	MCAT	1	0.9	0.7	0.5	0	-1
* Sin	Calculator	1	0.5	0.707	0.866	1	0
	MCAT	0	0.5	0.7	0.9	1	0

* Notice the value pattern 0 → 1, 1 → 0

Logs & Antilogs

Tutorial video 7/8 → LEAH4SCI.COM/MCATMATH

$p\# = -\log \#$ $\quad 10^{-p\#} = \#$

$-\log(1\times10^{-\#}) = \#$ $\quad 10^{-\#} = 1\times10^{-\#}$

-log range values to know

$X - 1 = \#$

	Calculator	MCAT
$-\log 8\times10^{-x}$	$= \#.097$	$\rightarrow \#.1$
$-\log 5\times10^{-x}$	$= \#.301$	$\rightarrow \#.3$
$-\log 3\times10^{-x}$	$= \#.523$	$\rightarrow \#.5$
$-\log 2\times10^{-x}$	$= \#.699$	$\rightarrow \#.7$

MCAT PHYSICS KINEMATICS

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Complete MCAT Kinematics video series:

Leah4sci.com/MCAT PHYSICS

Key

Δ = delta = change = final - initial (f-i)
x = distance or displacement
v = velocity
a = acceleration
t = time

4 units to look for in kinematic equations

x v a t

kinematic formulas	has units	missing
$x = x_i + vt$	x v t	a
$v_f = v_i + at$	v a t	x
$v_f^2 = v_i^2 + 2a\Delta x$	x v a	t
$x = v_i t + \frac{1}{2}at^2$	x a t	v_f

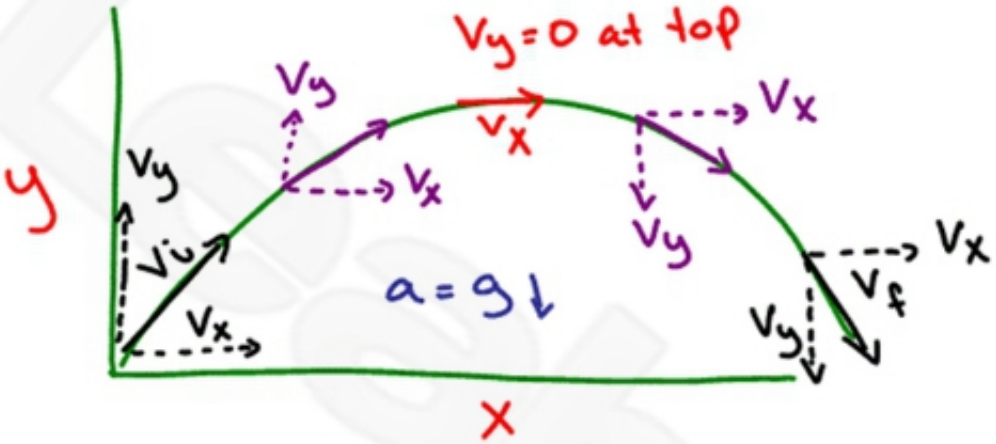
Alternate formats for above equations

$X_f = X_i + Vt \rightarrow X = Vt \rightarrow X = V_{avg}t \rightarrow X = \frac{V_1 + V_2}{2} \cdot t$

$V_f^2 = V_i^2 + 2a\Delta X \rightarrow V_f^2 = V_i^2 + 2ad$ ← distance

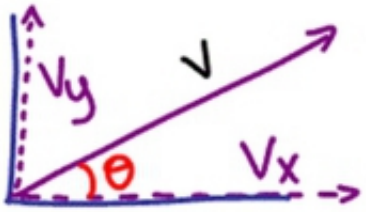
$X = V_i t + \frac{1}{2}at^2 \rightarrow X_f = X_i + V_i t + \frac{at^2}{2}$

PROJECTILE MOTION



V_i = upward
V_f = down
$a_y = g$ = down
a_x = zero
V_x = constant

Kinematic Trigonometry → LEAH4SCI.COM/MCATMATH



$V_x = V\cos\theta$

$V_y = V\sin\theta$

$V = \sqrt{V_x^2 + V_y^2}$

MCAT PHYSICS - FORCES

MCAT CHEAT SHEET STUDY GUIDE

F = Force unit: N = Newtons = $kg \cdot \frac{m}{s^2}$

$F = ma \rightarrow m\frac{v}{t} \rightarrow kg \cdot \frac{m}{s} \cdot \frac{1}{s} \rightarrow kg\frac{m}{s^2}$

(kg, m/s^2)

Weight + Gravity

$a_g = g$ near earth's surface $\sim 10\ m/s^2$

Weight $W = F_g = ma_g = mg$

Far from surface

$F = G\frac{m_1 m_2}{r^2}$ ← MCAT provided

$F \propto \frac{1}{r^2}$

$\uparrow F \rightarrow \downarrow r^2$

$\downarrow F \rightarrow \uparrow r^2$

Equilibrium

$\Sigma F = ma \rightarrow \Sigma F_x = ma_x$, $\Sigma F_y = ma_y$

$F_{net} = \sqrt{\Sigma F_x^2 + \Sigma F_y^2}$

Friction

$F_f = \mu N$

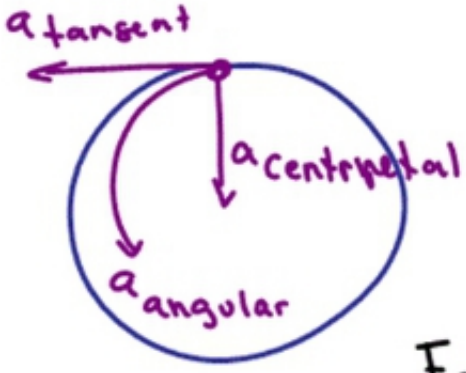
μ_s = Static$_f$ = prevents motion

$0 \leq f_s \leq \mu_s N$

μ_k = kinetic$_f$ = slows object in motion

$f_k = \mu_k N = \mu_k \cdot mg$

Centripetal Motion

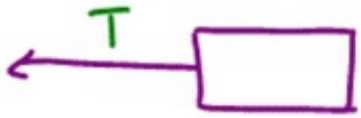


F_c keeps object on circular path

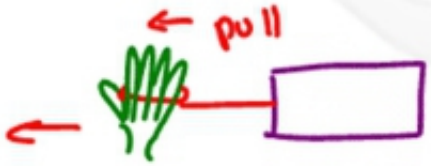
$a_c = \frac{v^2}{r}$ $F_c = ma_c \rightarrow m\frac{v^2}{r}$

$F_c = m\frac{v^2}{r} \rightarrow kg\ \frac{m^2}{s^2} \cdot \frac{1}{m} \rightarrow kg\ \frac{m}{s^2} = N$

Tension T → pulling force

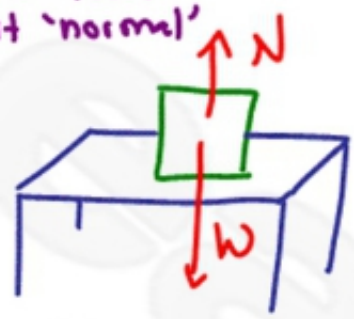


imagine hand pulls

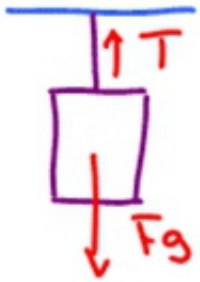


Free body Diagrams

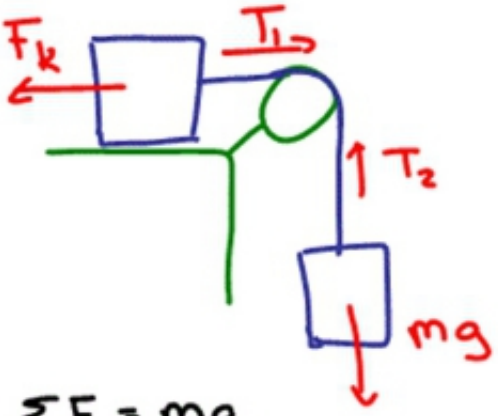
N = Normal force keeps it 'normal'



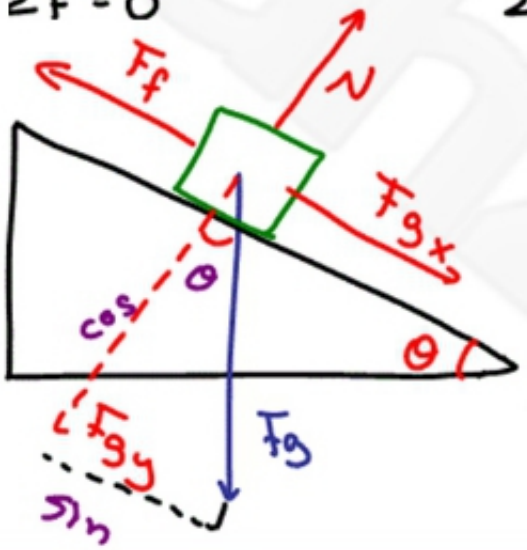
$\Sigma F = 0$



$\Sigma F = 0$



$\Sigma F = ma$



* exception: $a_x = \sin\theta$

$a_y = \cos\theta$

$\Sigma F = ma_x = mg\sin\theta - F_f$

TORQUE + ROTATIONAL EQ.

MCAT CHEAT SHEET STUDY GUIDE

Comparison of linear & Angular Components

	Displacement	velocity	acceleration
Linear unit	x	v_i, v_f	a
Angular Unit	θ theta	ω omega	α alpha

Linear Equation

$$x_f = x_i + vt$$

$$v_f = v_i + at$$

$$v_f^2 = v_i^2 + 2a\Delta x$$

$$\Delta x = v_i t + \frac{1}{2}at^2$$

Angular version

$$\theta_2 = \theta_1 + \omega t$$

$$\omega_f = \omega_i + \alpha t$$

$$\omega_f^2 = \omega_i^2 + 2\alpha\Delta\theta$$

$$\Delta\theta = \omega_i t + \frac{1}{2}\alpha t^2$$

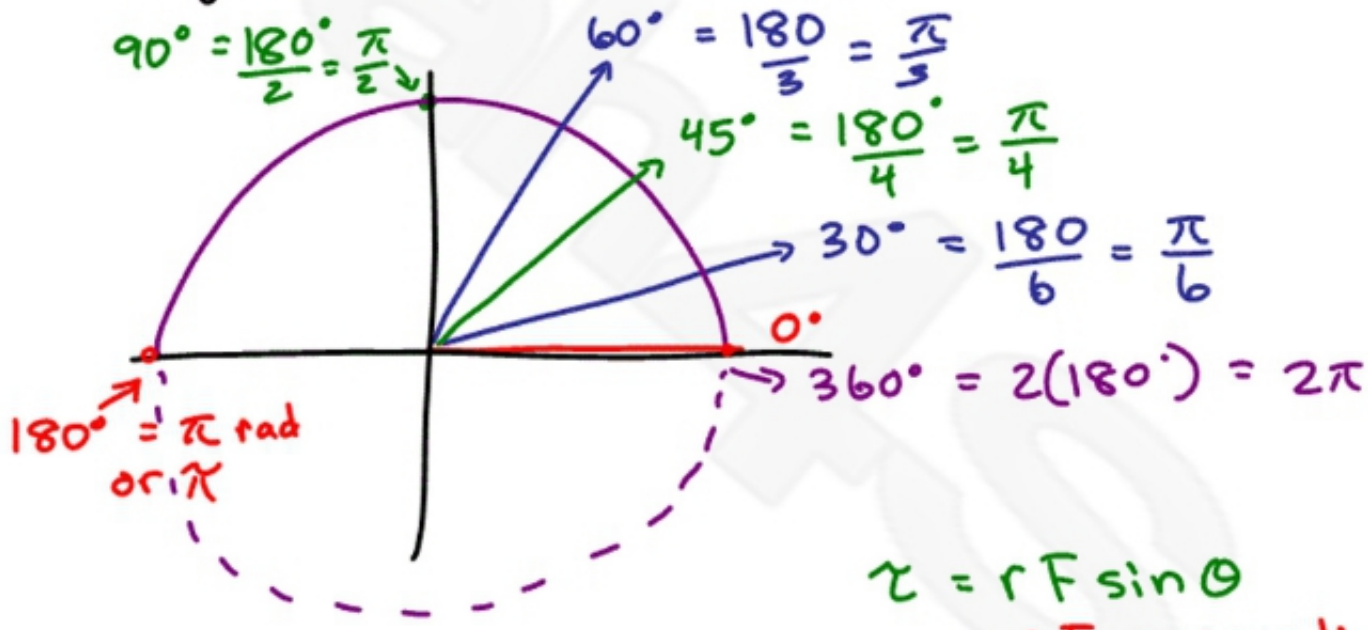
Converting linear to angular

$$\theta = \frac{s}{r}$$ ← arc length

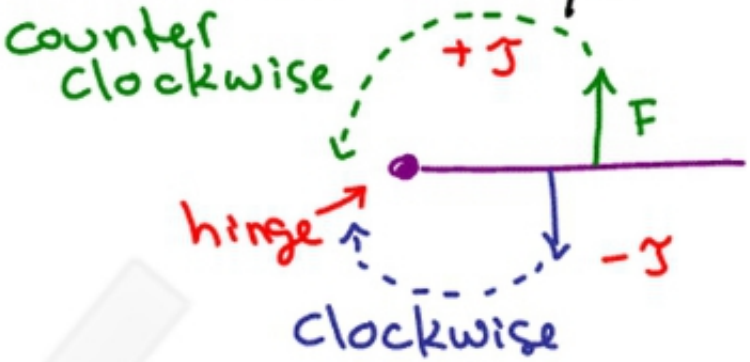
$$\omega = \frac{v}{r} = \frac{\theta}{t}$$

$$\alpha = \frac{a}{r} = \frac{\omega}{t}$$

Degrees to π radians



τ ← tau = torque



$\tau = rF\sin\theta$
$= rF_{perpendicular}$
$= F\ell$ ← lever arm
$= I\alpha$
$= \Delta L / \Delta t$

Rotational Equilibrium

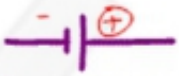
$\Sigma J = 0$

$\Sigma F = 0$ $\quad \Sigma F_x = 0$ $\quad \Sigma F_y = 0$

CIRCUITS

MCAT CHEAT SHEET STUDY GUIDE

Circuit Elements



Battery

Resistor

Capacitor

Switch

Units

V = voltage Ω (ohm) = resistance = R I = current

P = power Q = charge C = capacitance E = electric Field

Resistors & Capacitors In Series

$R_{eq} = R_1 + R_2 + R_3$

↑ R_{eq}

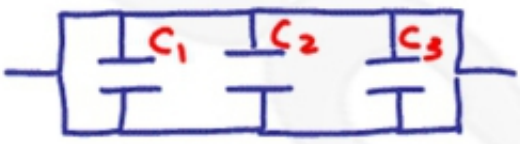
$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2} + \frac{1}{C_3}$

↓ C_{eq}

Resistors & Capacitors In Parallel

$\frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$

↓ R_{eq}



$C_{eq} = C_1 + C_2 + C_3$

↑ C_{eq}

Circuit Equations

I = + → (−)

circuits

$$V = IR \rightarrow I = \frac{V}{R} \rightarrow R = \frac{V}{I}$$

closed switch

Power

$$P = IV = \frac{V^2}{R} = I^2 R$$

Current

$$I = \frac{\Delta Q}{\Delta t} = A \text{ (amperes)}$$

Capacitance

$$C = \frac{Q}{V} = \text{Farad} = \varepsilon_0 \frac{A}{d}$$

ε_0: permittivity of free space

Resistance

$$R = \rho \frac{L}{A}$$

ρ: resistivity

$$E = \frac{V}{d}$$

Electric Field

PE capacitor

$$U = \frac{1}{2} QV = \frac{1}{2} CV^2 = \frac{Q^2}{2C}$$

MITOSIS - MEIOSIS

MCAT CHEAT SHEET STUDY GUIDE

MCAT Tutorial videos and more: Leah4sci.com/Mitosis

Interphase → duplication of DNA + organelles

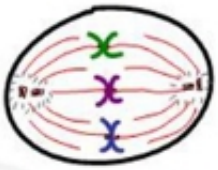
PMAT = Prophase Metaphase Anaphase Telophase

Mitosis - asexual nuclear division

Prophase

Nuclear envelope breaks, chromatin condense, centrosomes separate, formation of mitotic spindle

Metaphase



DNA lines up at Metaphase Plate due to mitotic spindle pulling on sister chromatids via kinetichores

Anaphase

Centrosomes push out, microtubules shorten, sister chromatids separate

Telophase

Nuc envelope reforms, chromosomes decondense, mitotic spindle breaks

cytokinesis simultaneous

Cytokinesis - cell division → 2 identical diploid daughter cells

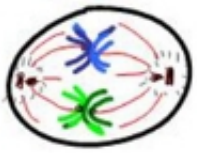
homologs: equivalent chromosome from mother + father

diploid - DNA from both parents haploid - from 1 parent

chromatid

Meiosis - Sexual Nuclear Division → 4 haploid gametes

Prophase I  Nuc envelope breaks, centrosomes separate, spindle fibers form crossing over between homologs

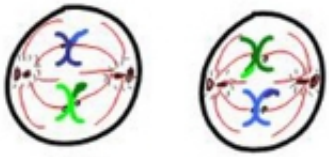
Metaphase I  Homologs line up at metaphase plate. Spindle fibers attached to kinetochores

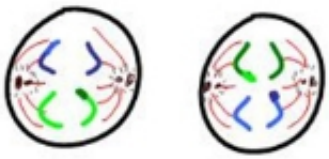
Anaphase I  Homologs pulled apart but sister chromatids are still attached

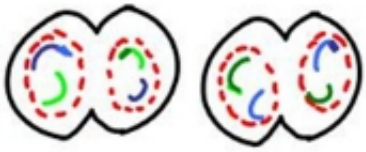
Telophase I  Nuc envelope reforms around sister chromatids. Cytokinesis happens at the same time

Meiosis I Product: 2 haploid daughter cells with duplicate DNA. (double mothers or fathers DNA)

Prophase II  Nuc envelope breaks, centrosomes separate, spindle fibers form
No crossing over

Metaphase II  Sister chromatids line up at metaphase plate (90° plate turn)

Anaphase II  Cohesin breaks, sister chromatids pulled apart

Telophase II  Nuc envelope reforms around haploid chromatids which decondense to chromatin
cytokinesis at same time

Product Meiosis II: 4 haploid gametes

Spermatogenesis → 4 spermatids
oogenesis → 1 ootid + 2 (or 3) polar bodies

Mitosis	vs	Meiosis
somatic cells		germ cells
1 round		2 rounds
2 diploids		4 haploids
no crossing over		crossing over M_1

cohesin - binds sister chromatids

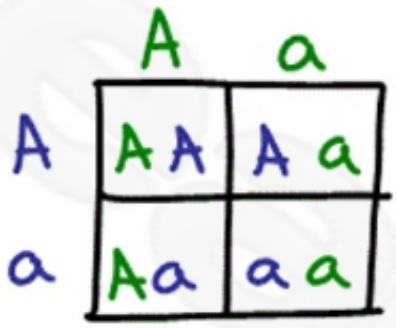
sister chromatids - copy of haploid (1-parent) DNA

PUNNETT SQUARE RATIOS

MCAT STUDY GUIDE

MCAT GENETICS Leah4Sci.com/MCAT

Monohybrid Cross Aa x Aa



phenotype = 3:1
3 dominant AA or Aa
1 recessive aa

Genotype 1:2:1

1	homozygous	dominant	1/4 = 25%	AA
2	heterozygous		2/4 = 50%	Aa
1	homozygous	recessive	1/4 = 25%	aa

Dihybrid Cross AaBb x AaBb

think (Aa x Aa)(Bb x Bb)

	AB	Ab	aB	ab
AB	A A B B	A A B b	A a B B	A a B b
Ab	A A B b	A A b b	A a B b	A a b b
aB	A a B B	A a B b	a a B B	a a B b
ab	A a B b	A a b b	a a B b	a a b b

Phenotype

9 : 3 : 3 : 1

9/16 9 = dominant A & B

AA & Aa BB & Bb

3/16 3 & 3 = 1 dominant

3: AA & Aa with bb

3: aa with BB & Bb

1/16 1 = homozygous recessive aabb

Genotype

	A	a
A	AA	Aa
a	Aa	aa

	B	b
B	BB	Bb
b	Bb	bb

Consider above as

$\frac{AA}{BB} = \frac{1}{4}$ $\frac{Aa}{Bb} = \frac{2}{4} = \frac{1}{2}$ $\frac{aa}{bb} = \frac{1}{4}$

Homozygous Dominant $= \frac{1}{16} = \frac{1}{4}AA \cdot \frac{1}{4}BB$

Homozygous Recessive $= \frac{1}{16} = \frac{1}{4}aa \cdot \frac{1}{4}bb$

Hetero Aa homo BB or bb $\frac{2}{16} = \frac{2}{4}Aa \times \frac{1}{4}\frac{BB \text{ or}}{bb}$

homo AA or aa hetero Bb $\frac{2}{16} = \frac{1}{4}\frac{AA \text{ or}}{aa} \times \frac{2}{4}Bb$

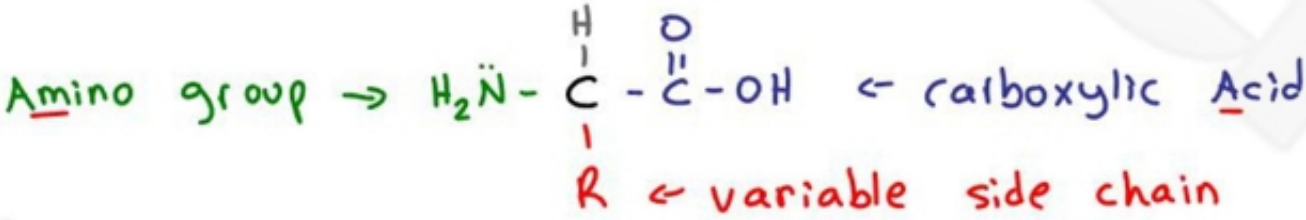
Heterozygous in Aa + Bb $\frac{4}{16} = \frac{2}{4}Aa \times \frac{2}{4}Bb$

AMINO ACIDS

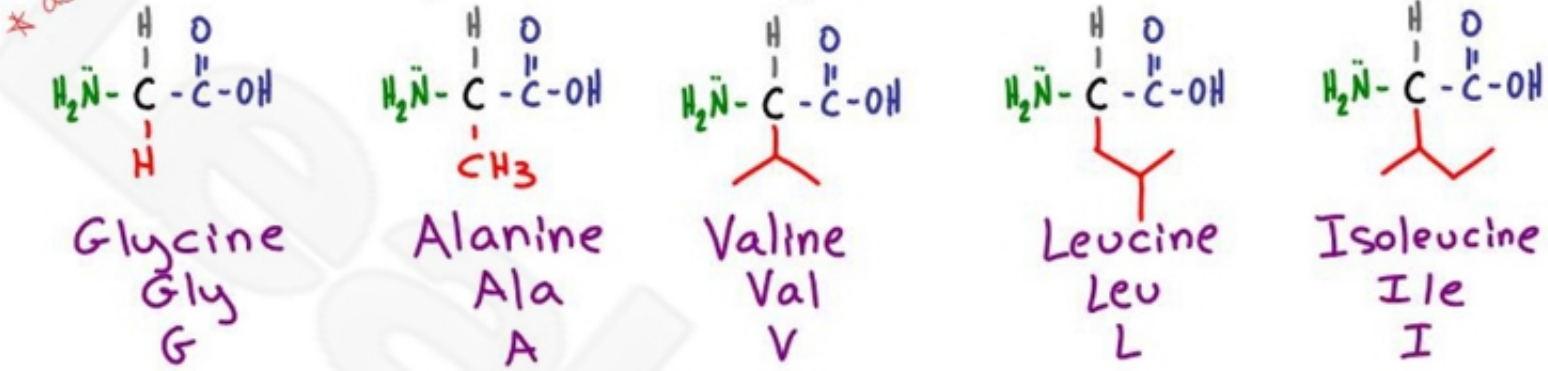
MCAT CHEAT SHEET STUDY GUIDE

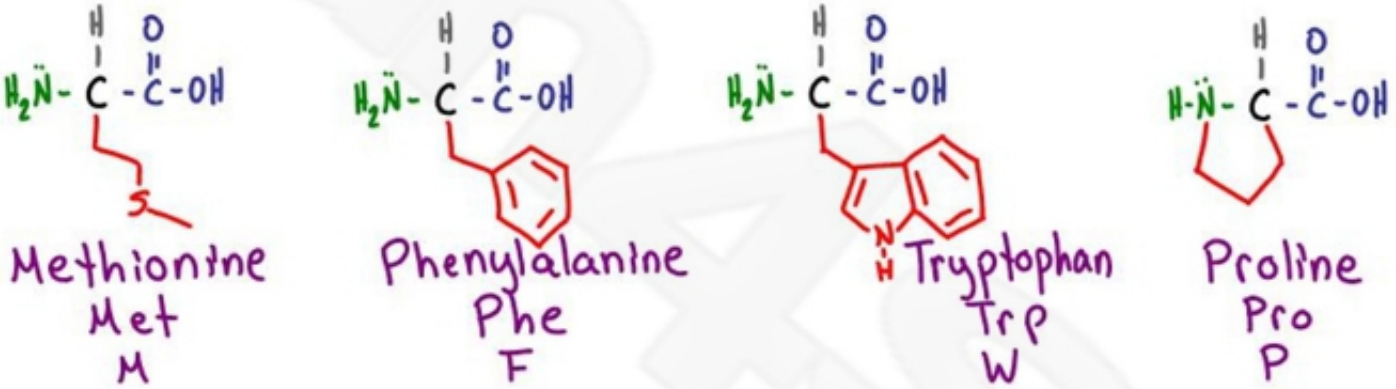
MCAT Tutorial Videos, Cheat Sheets & More

Leah4sci.com/mcat

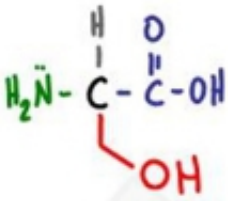


Non-polar Hydrophobic Amino Acids

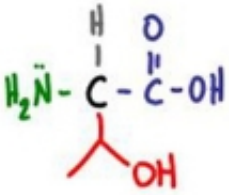




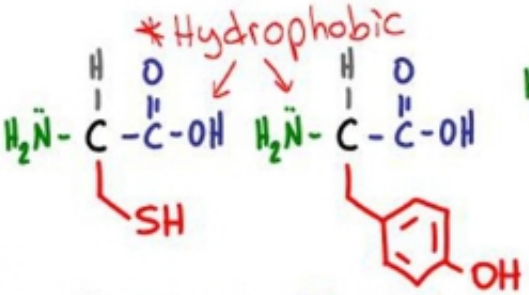
Polar Hydrophilic Amino Acids



Serine
Ser
S

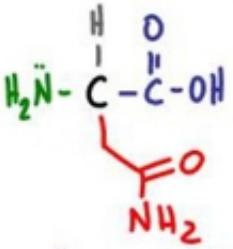


Threonine
Thr
T

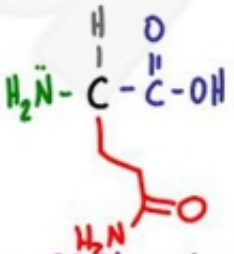


Cysteine
Cys
C

Tyrosine
Tyr
Y

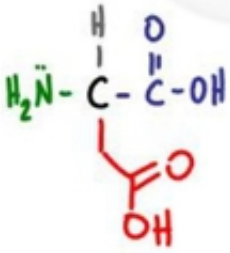


Asparagine
Asn
N

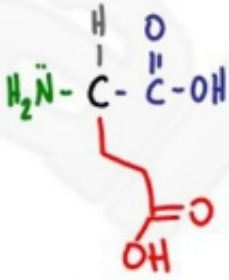


Glutamine
Gln
Q

Acidic Amino Acids

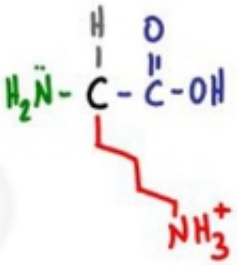


Aspartic Acid
Asp
D

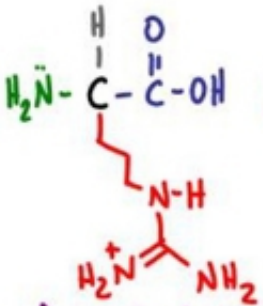


Glutamic Acid
Glu
E

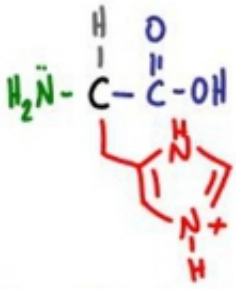
Basic Amino Acids



Lysine
Lys
K

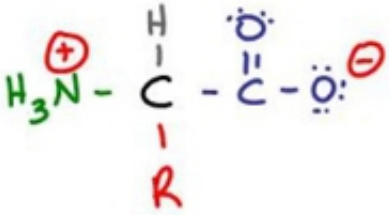


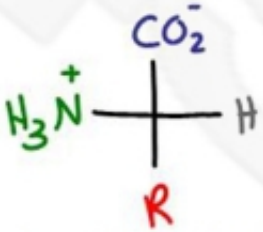
Arginine
Arg
R



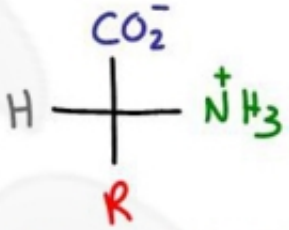
Histidine
His
H

Zwitterion





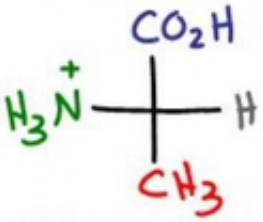
L - amino acid



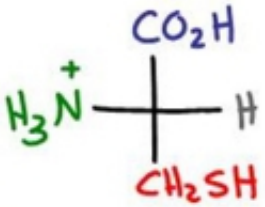
D - amino acid

L = most common in nature
L can be R or S

pH < pka = protonated
pH > pka = deprotonated



L-Alanine = S



L-Cysteine = R

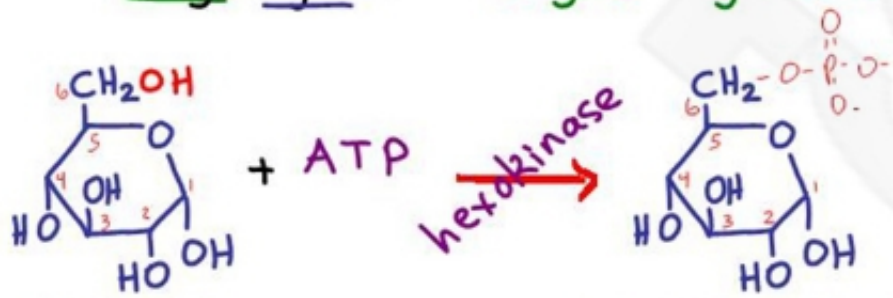
GLYCOLYSIS REACTIONS

MCAT CHEAT SHEET STUDY GUIDE

MCAT Tutorial videos and more: Leah4sci.com/MCAT

Glycolysis: Glyco = glucose Lysis = break

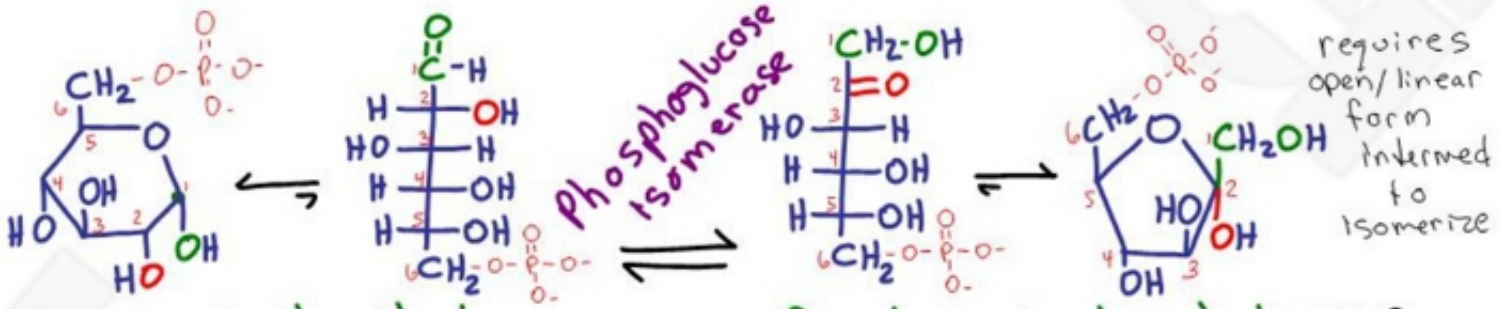
Step 1



Glucose Glucose-6-phosphate G6P

one way rxn
traps glucose in cell

Step 2

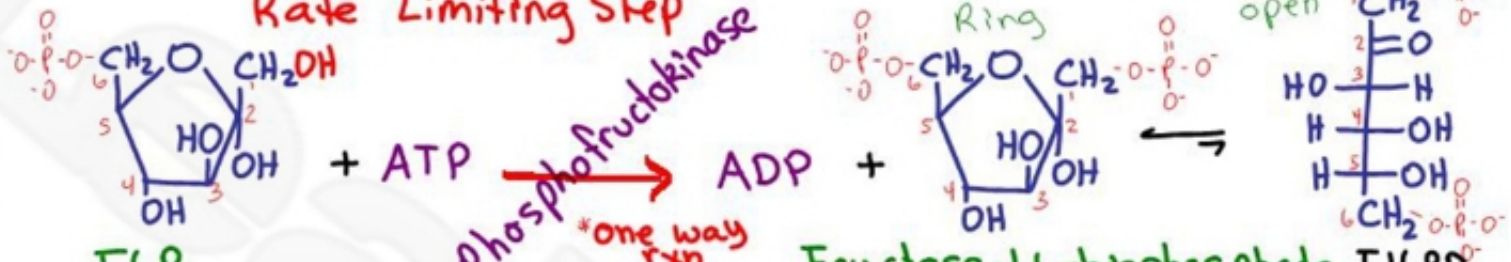


Glucose-6-phosphate Fructose-6-phosphate F6P

requires open/linear form intermed to isomerize

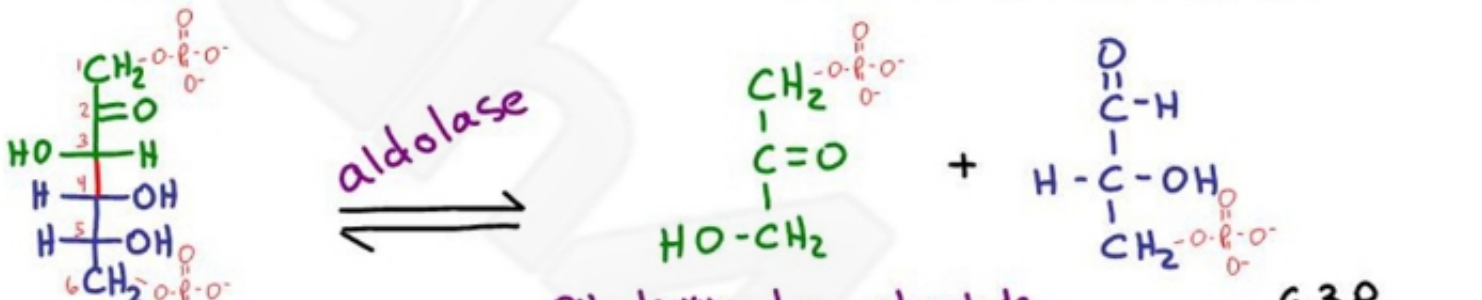
Step 3

Rate Limiting Step



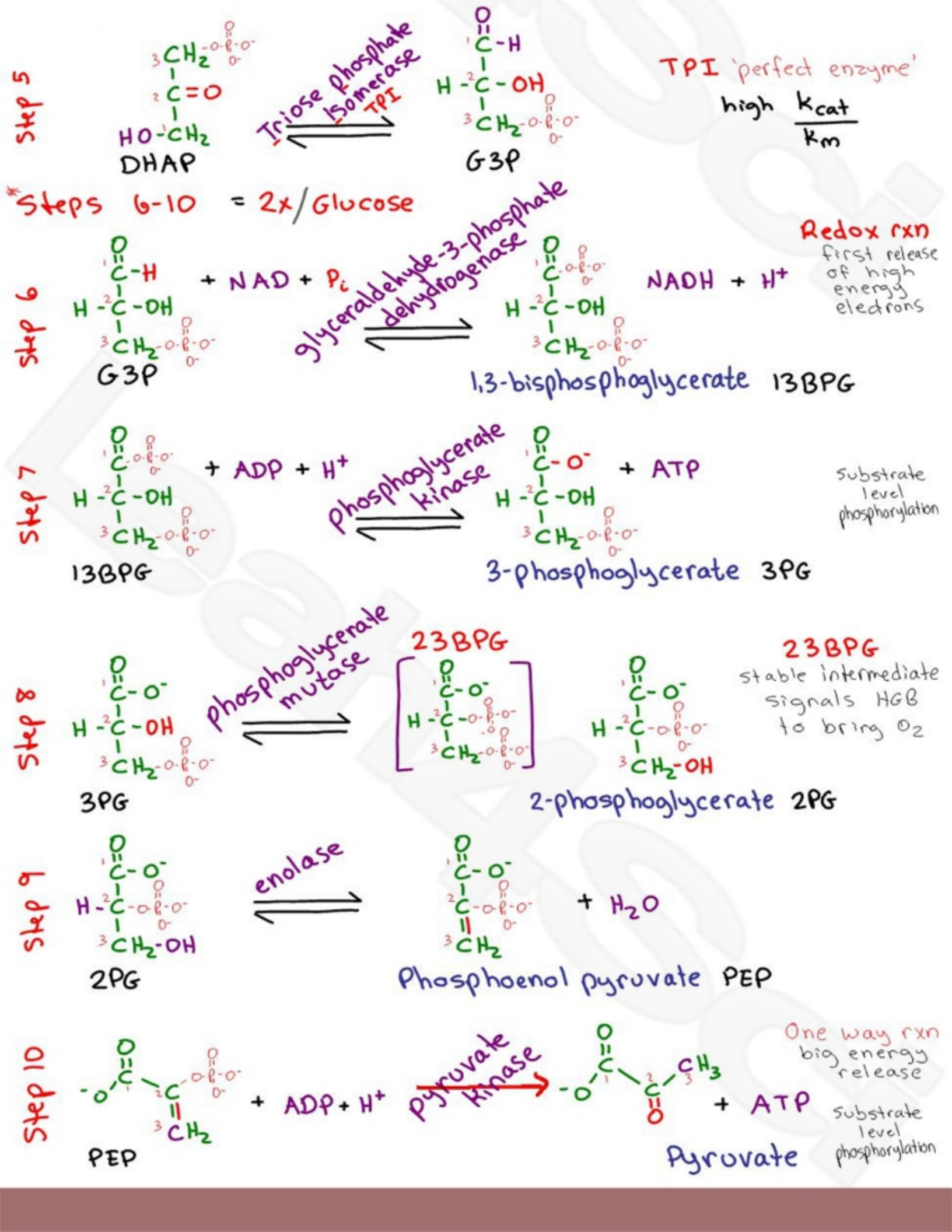
F6P Fructose-1,6-bisphosphate F16BP

Step 4



F16BP
open form

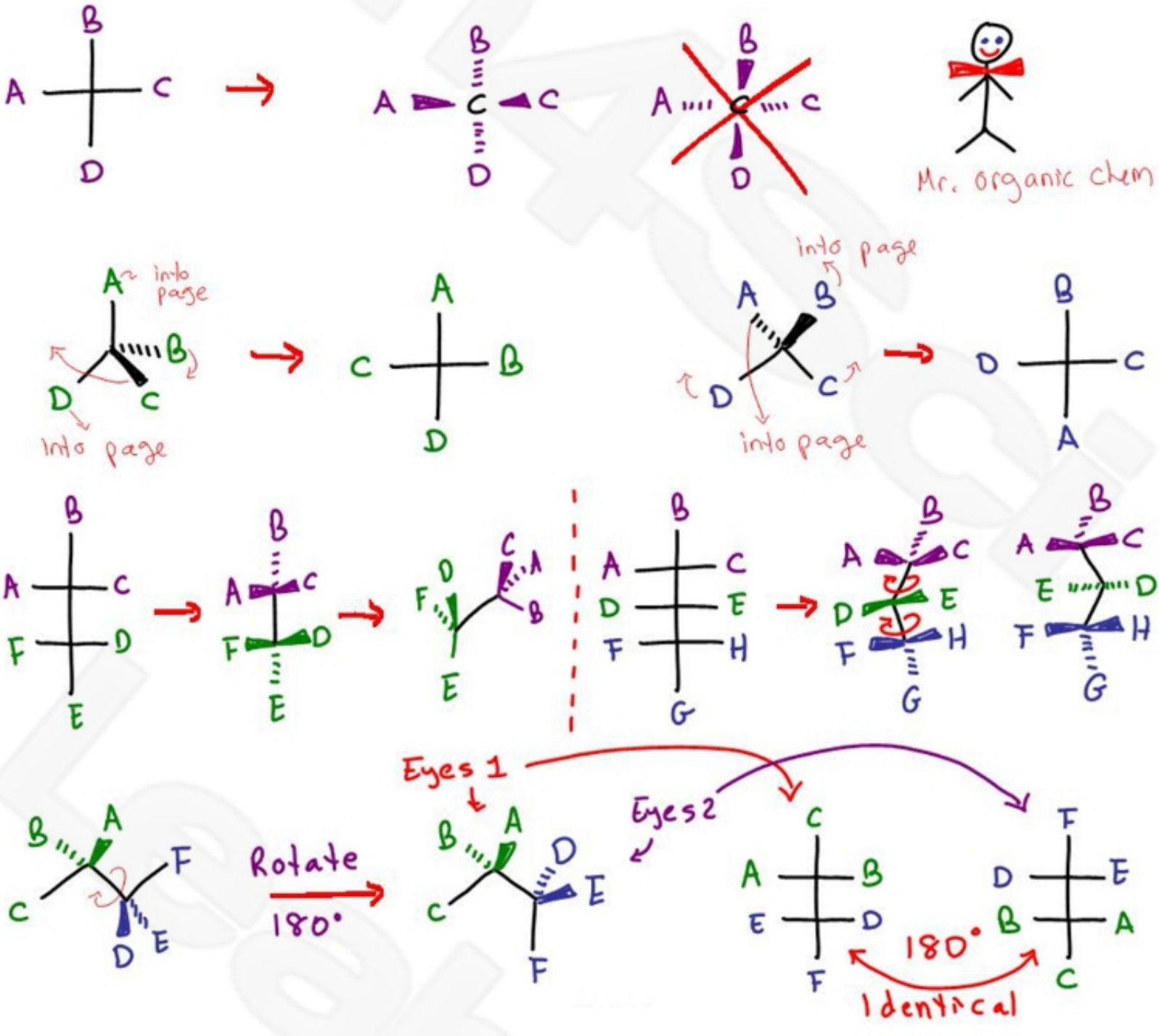
Dihydroxyacetone phosphate DHAP + Glyceraldehyde-3-phosphate G3P

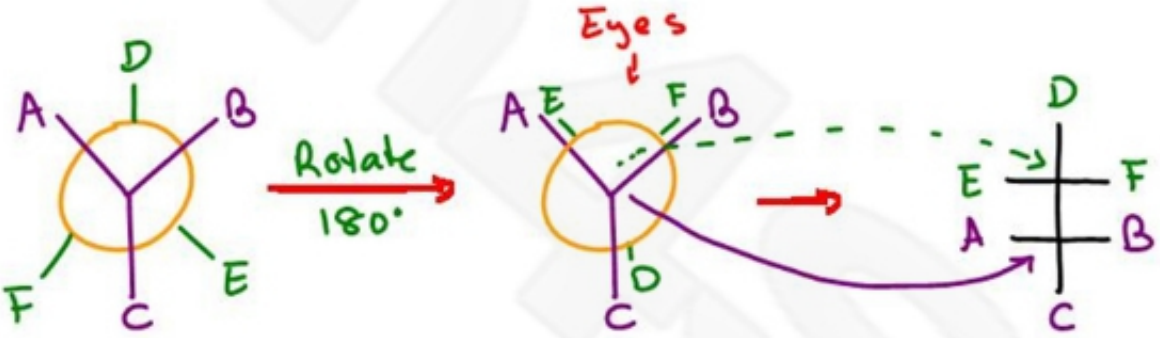

Step 5
DHAP
Triose phosphate Isomerase TPI
G3P
TPI 'perfect enzyme'
high $\frac{k_{cat}}{K_m}$
*Steps 6-10 = 2x/Glucose
Step 6
+ NAD + P_i
glyceraldehyde-3-phosphate dehydrogenase
NADH + H^+
Redox rxn
first release of high energy electrons
G3P
1,3-bisphosphoglycerate 13BPG
Step 7
+ ADP + H^+
phosphoglycerate kinase
+ ATP
substrate level phosphorylation
13BPG
3-phosphoglycerate 3PG
Step 8
phosphoglycerate mutase
23BPG
23BPG
stable intermediate
signals HGB to bring O_2
3PG
2-phosphoglycerate 2PG
Step 9
enolase
+ H_2O
2PG
Phosphoenol pyruvate PEP
Step 10
+ ADP + H^+
pyruvate Kinase
+ ATP
One way rxn
big energy release
substrate level phosphorylation
PEP
Pyruvate

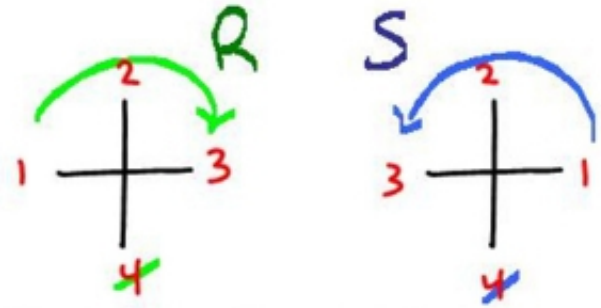
FISCHER PROJECTIONS

ORGO/MCAT CHEAT SHEET ©LEAH4SCI

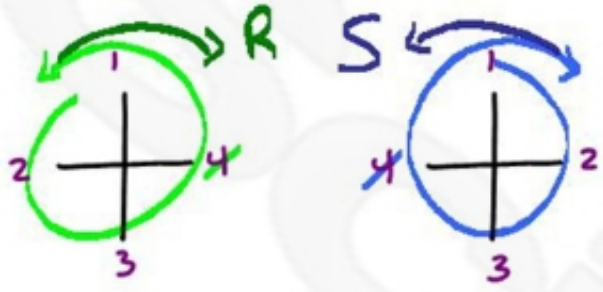
Complete Video series and Practice Quiz: Leah4sci.com/Fischer



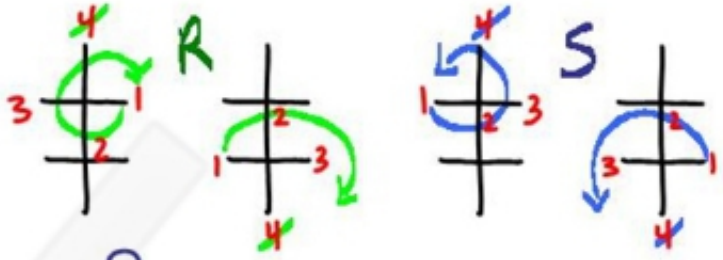


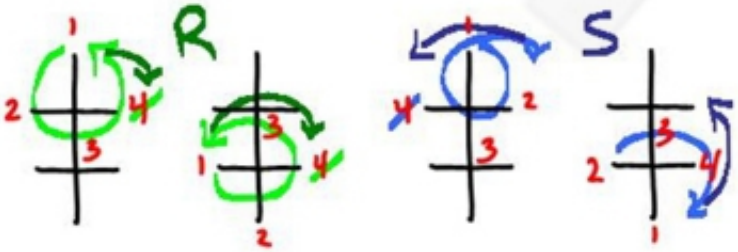


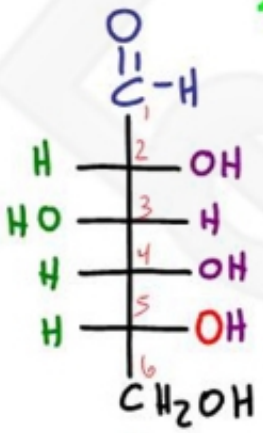
4 back = Ideal



4 forward = reverse R+S



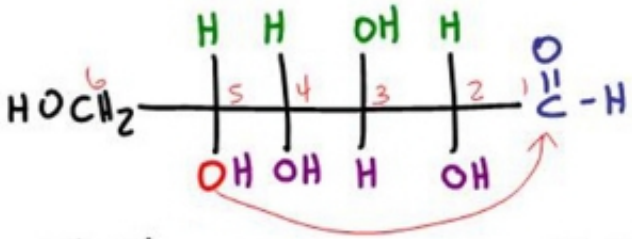


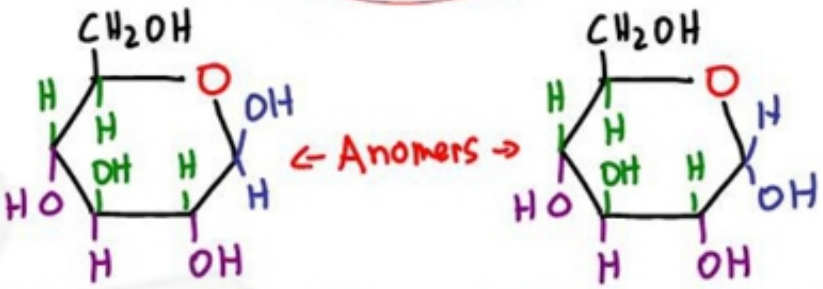


D-glucose

drop it
Right Down

other side
is
Left up

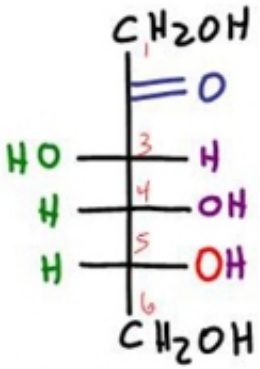




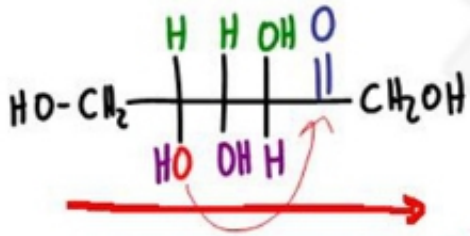
← Anomers →

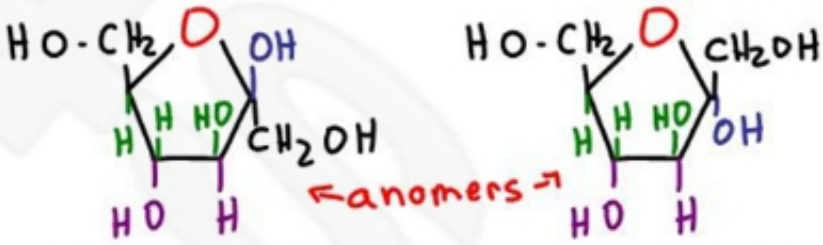
β-D-glucopyranose

α-D-glucopyranose



D-fructose





β-D-fructofuranose

← anomers →

α-D-fructofuranose

FUNCTIONAL GROUPS

ORGANIC CHEMISTRY CHEAT SHEET

Learn how to name each group: Leah4sci.com/Naming

'R' Group ← not a real group

'R' represents the 'Rest' of the molecule

Alkane

$R-CH_2-CH_2-R$

ex 

hexane

Alkene

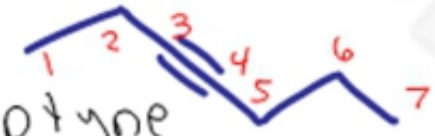
$R-CH=CH-R$

ex 

cis - 3 - octene

Alkyne

$R-C\equiv C-R$

ex 

3-heptyne

Alkyl Halide

$R-X$

X = F, Cl, Br, I

ex 

1-chlorobutane

Alcohol

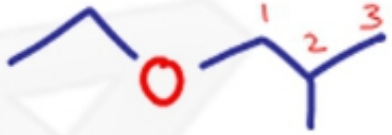
$R-OH$

ex 

2-methyl-2-butanol

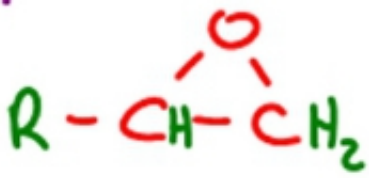
Ether

R-O-R'

ex 

1-ethoxy-2-methylpropane

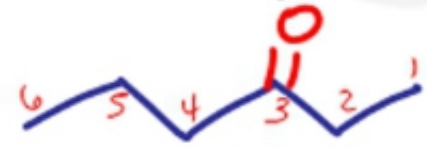
Epoxide



ex 

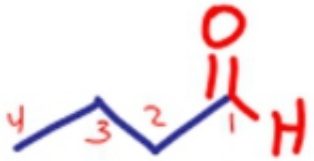
1,2-epoxycyclohexane

Ketone

ex 

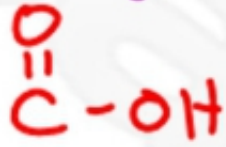
3-hexanone

Aldehyde

ex 

butanal

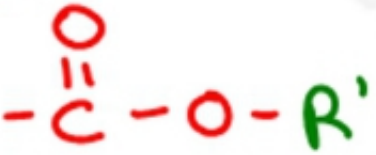
Carboxylic Acid

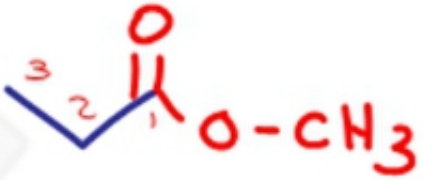


ex 

pentanoic acid

Ester

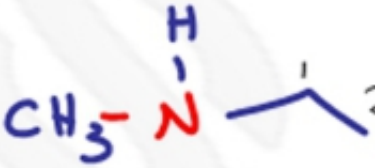


ex 

methyl propanoate

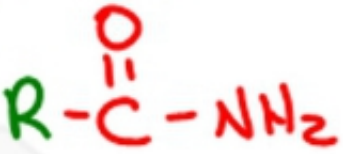
Amine

R-NH$_2$

ex 

N-methylethylamine

Amide



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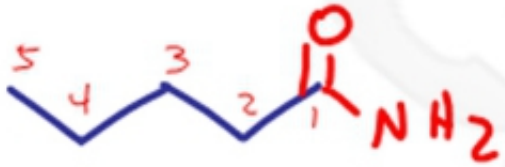
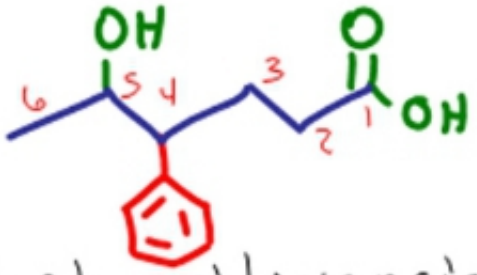


pentanamide

Phenyl

ex

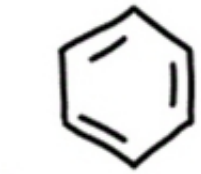


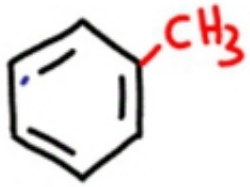
5-hydroxy-4-phenylhexanoic acid

COMMON AROMATIC COMPOUNDS

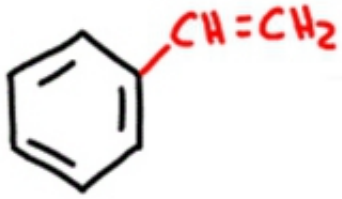
STUDY GUIDE © LEAH4SCI

Complete orgo naming tutorial video series
Leah4Sci.com/naming

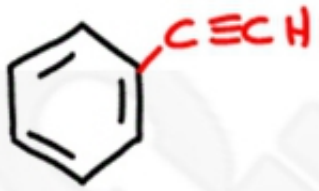

benzene



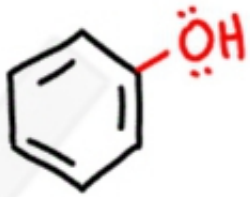
toluene



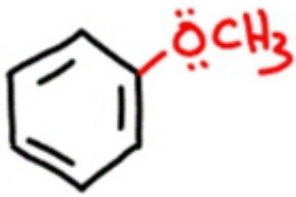
styrene



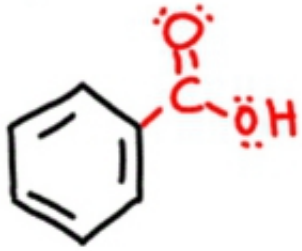
phenylacetylene



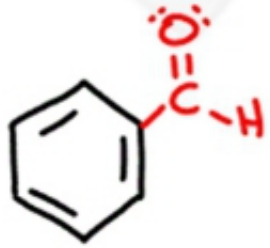
phenol



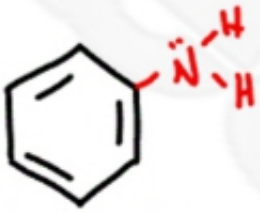
anisole



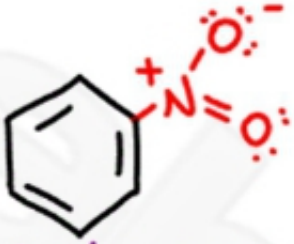
benzoic acid



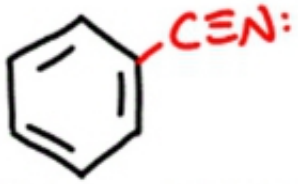
benzaldehyde



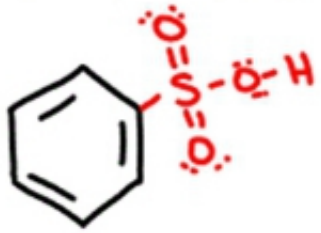
aniline



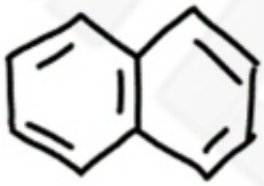
nitrobenzene

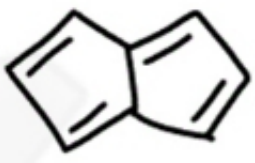


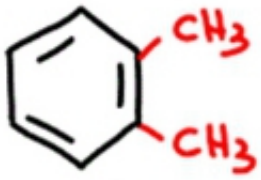
benzonitrile



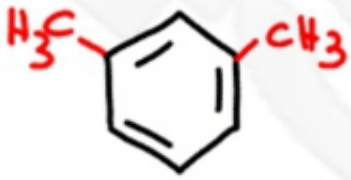
benzenesulfonic acid


napthalene

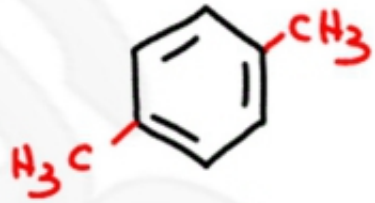

pentalene



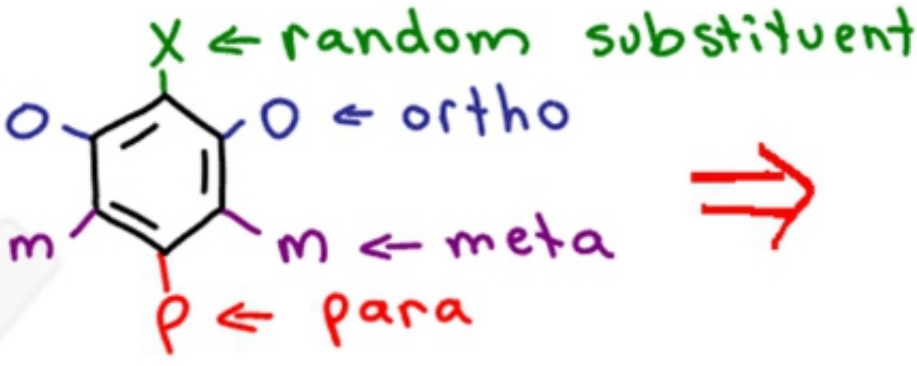
o-xylene
orthoxylene

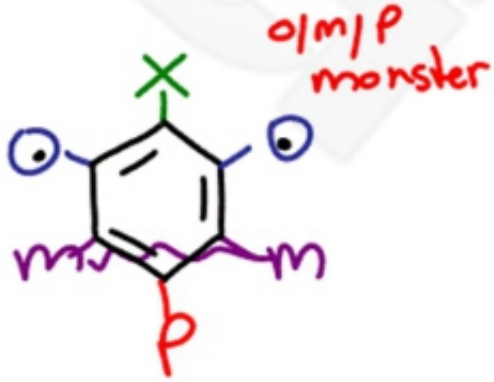


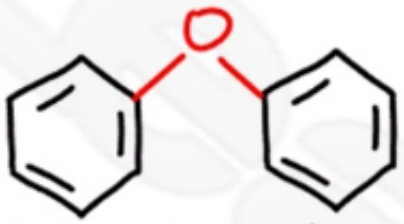
m-xylene
metaxylene



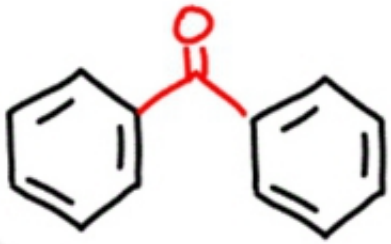
p-xylene
paraxylene



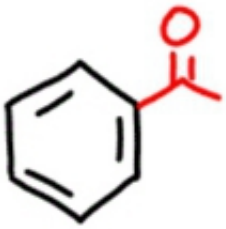




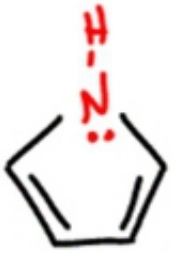
diphenyl ether



benzophenone



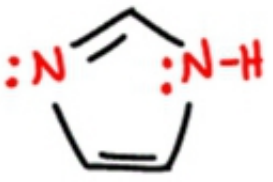
acetophenone



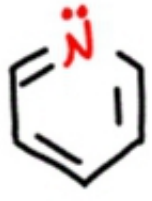
pyrrole

furan

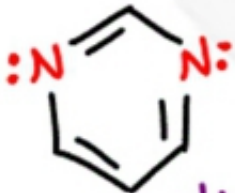
thiophene



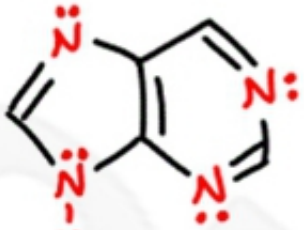
imidazole



pyridine



pyrimidine



purine

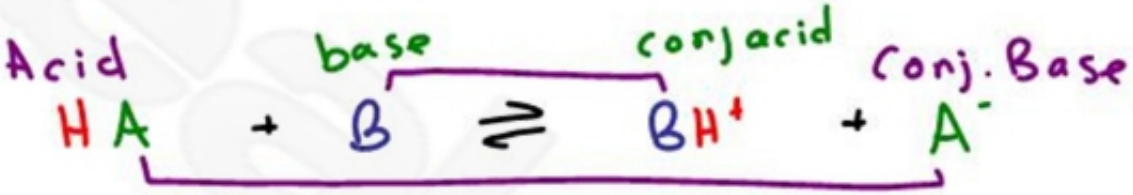
ACIDS & BASES

CHEAT SHEET STUDY GUIDE

Video series + Quiz - leah4sci.com/acidbase

	Acid: Litmus Red	Base Litmus Blue
Arrhenius	H^+ in H_2O ex. HCl	OH^- in H_2O ex NaOH
Bronsted-Lowry	H^+ donor ex NH_4Cl	Accepts H^+ NH_3
Lewis (electrons)	Accepts e^- pair ex $AlCl_3$	e^- pair donor ex. Cl^-

Acid - Base Reaction



Equations to recognize

$$K_a = \frac{[H^+][A^-]}{[HA]} \qquad pK_a = -\log(K_a) \rightarrow K_a \propto [H^+] \propto \frac{1}{pK_a}$$

Strong Acid ↑ $[H^+]$ ↑ K_a ↓ pK_a

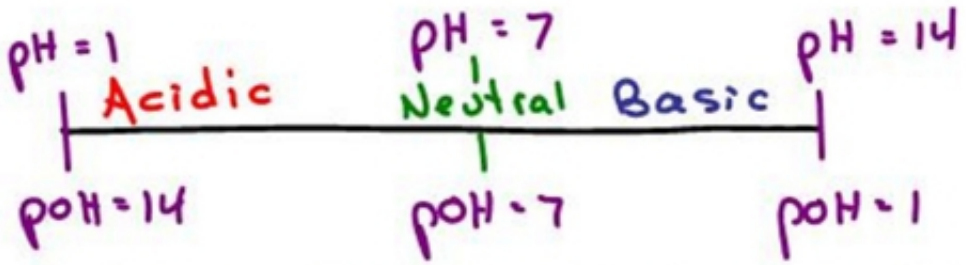
Weak Acid ↓ $[H^+]$ ↓ K_a ↑ pK_a

$pH = -\log[H^+]$ $\quad pH + pOH = 14$

$pOH = -\log[OH^-]$ $\quad pK_a + pK_b = pK_w = 14$

pH scale

pH → ← pOH



STRONG ACIDS FORM STABLE CONJUGATE BASES

CARIO

C = charge of acid or conj. base

A = Atom holding charge

R = Resonance

I = Inductive effect

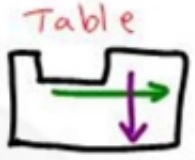
O = orbital / hybridization

Charge: + / δ+ more acidic } when compare species

− / δ− more basic }

Atom: In same period ↑ eneg ↑ acidity

In same group ↑ size ↑ acidity



Resonance: ↑ Res ↑ charge distribution ↑ acidity (Aromaticity = ↑ stable)

Inductive Effect: ↑ e⁻neg nearby atom ↑ acidity

Orbital / hybridization ↑ % S ↑ acidity

$sp = 50\% > sp^2 = 33\% > sp^3 = 25\%$

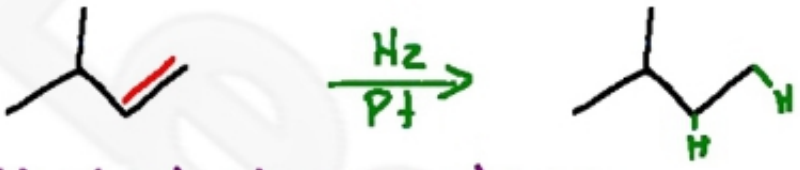
ALKENE REACTIONS

CHEAT SHEET STUDY GUIDE

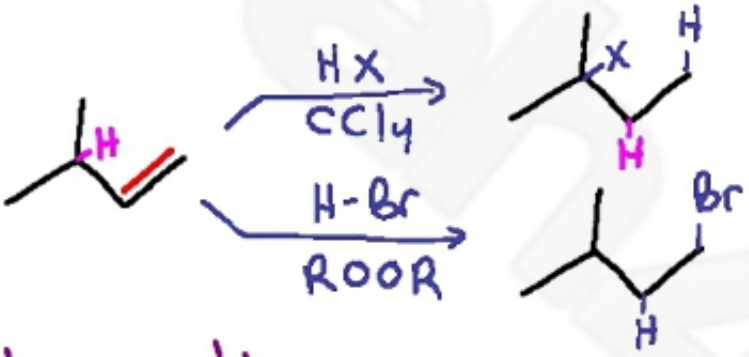
Entire Video series - leah4sci.com/alkene-reactions

Hydrogenation - Catalytic Reduction

Syn Addition



Hydrohalogenation



Mark, H-shift, C+

X = Cl, Br, I

ROOR = peroxides

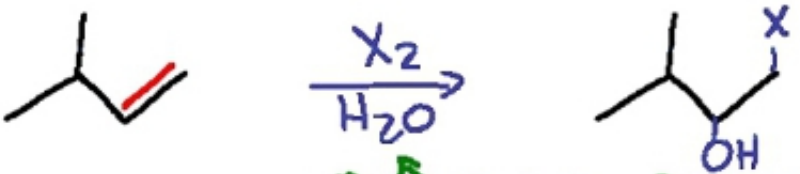
Anti-Mark

Halogenation

Anti-addition

X = Cl, Br

Halohydrin Formation

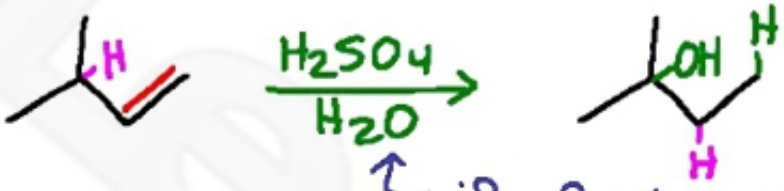


Anti, OH = Mark

No C+ X = Cl, Br

if ↖ ROH form ether

Acid Catalyzed Hydration

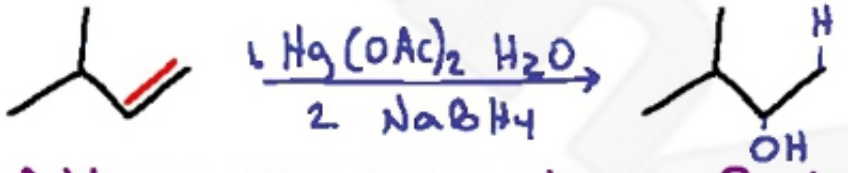


Mark, H-shift, C+

also see H^+/H_2O or H_3O^+

↑ if ROH used form ether

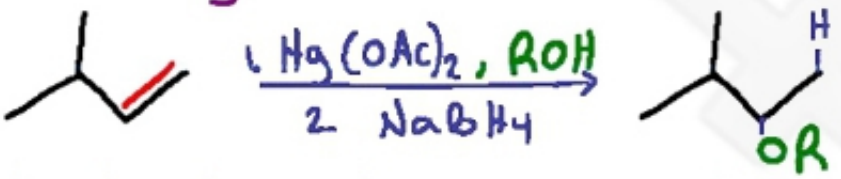
Oxymercuration - Reduction



Mark, no H-shift

Anti

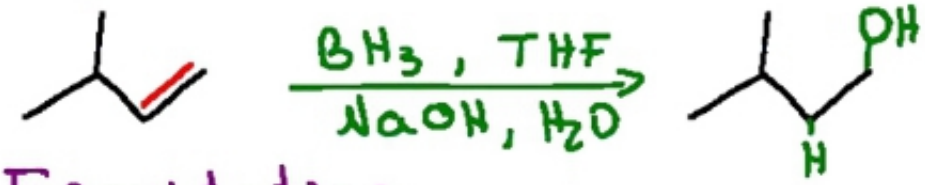
Alkoxymercuration- Reduction



Mark, no H-shift

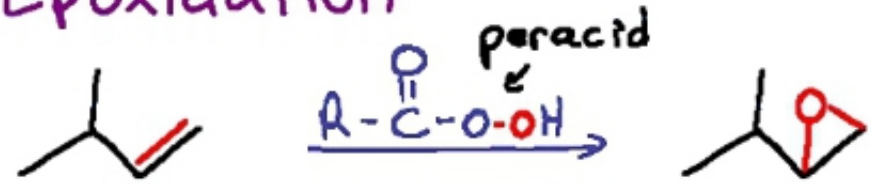
Anti

Hydroboration – Oxidation



Anti-Mark

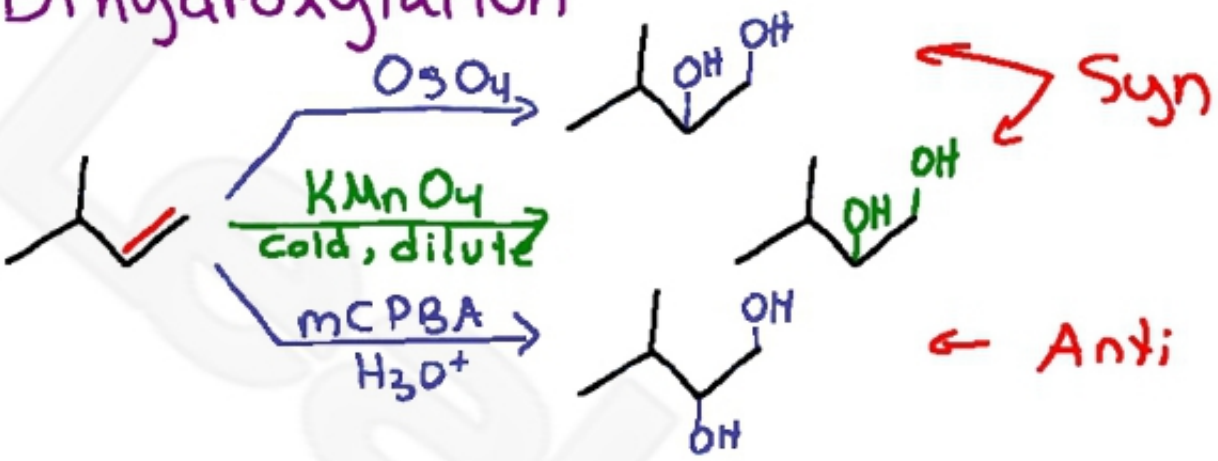
Epoxidation



Syn

mCPBA often used

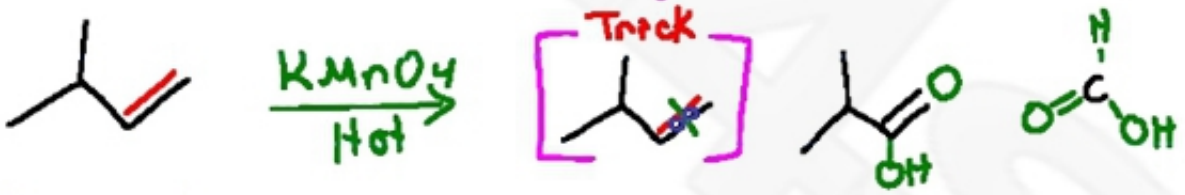
Dihydroxylation



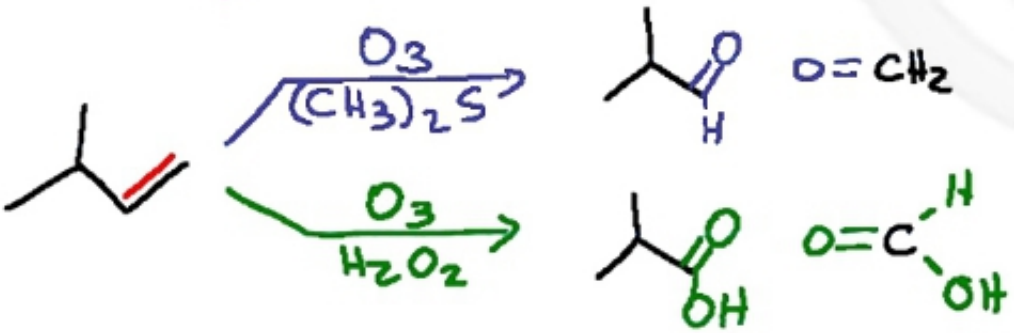
Syn

Anti

Oxidative Cleavage



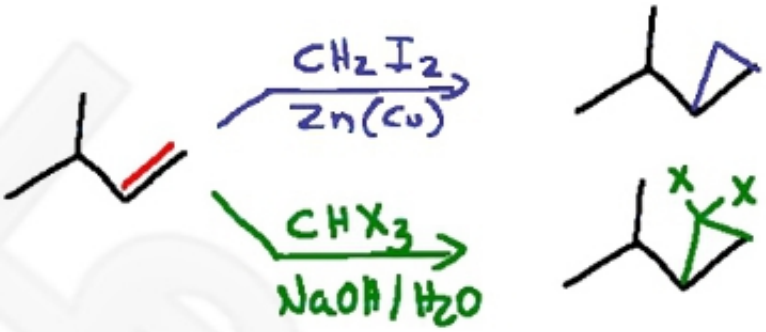
Ozonolysis



1°C → aldehyde

1°C → carboxylic acid

Cyclopropanation



← Simmons-Smith Rxn

Notes Key

Syn = Syn addition Anti = Anti-addition

Mark = Markovnikov Anti-Mark = anti-Markovnikov

C+ = carbocation Intermediate

H-shift = Hydride shift, C+ rearrangement

ALKYNE REACTIONS

CHEAT SHEET STUDY GUIDE

2-butyne $CH_3-C\equiv C-CH_3$ =

propyne $CH_3-C\equiv C-H$ =

Reduction

H_2, Pd or Pt ... → full reduction to alkane

Na°, NH_3 (l) → partial reduction trans alkene

H_2, Lindlar's Catalyst → Partial Reduction cis alkene

Hydration

Similar to $Hg(OAc)_2$

$HgSO_4$ (Hg^{2+}), H_2SO_4, H_2O → 2° enol → KET ⇌ ketone

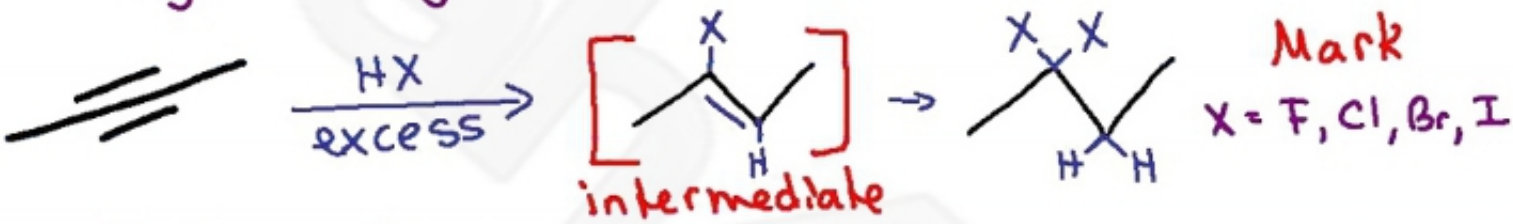
Mark, anti-addition

BH_3, THF; H_2O_2, OH^- → 1° enol → KET ⇌ aldehyde

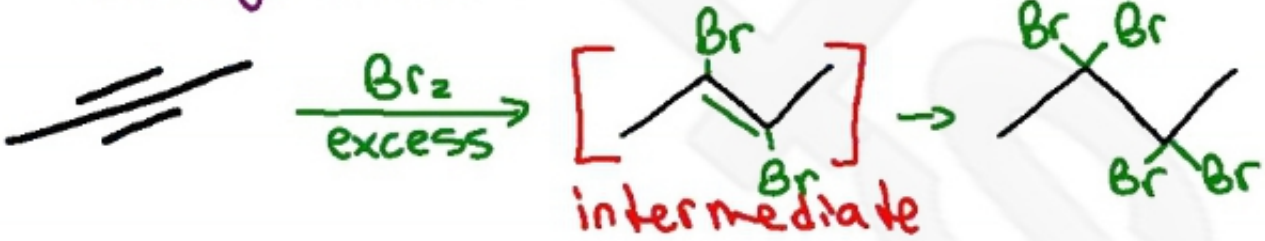
anti - Mark
syn addion

non-terminal = ketone

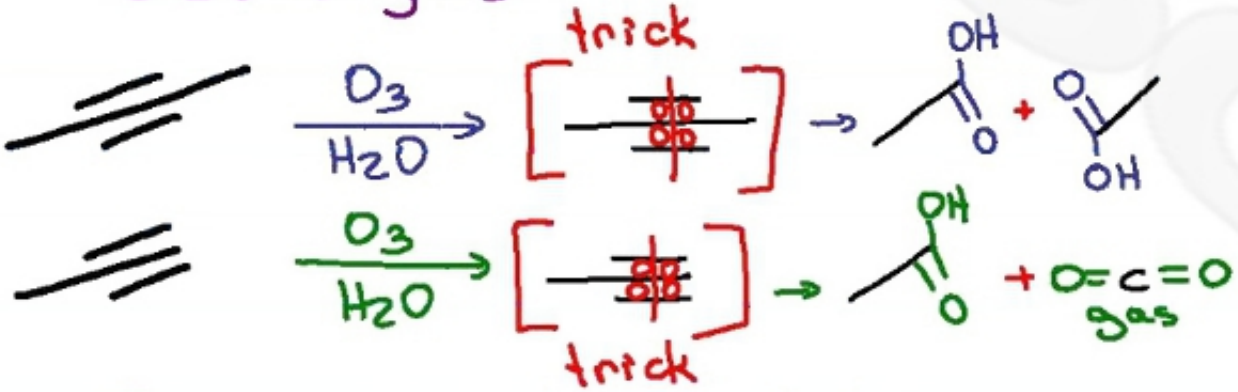
Hydrohalogenation



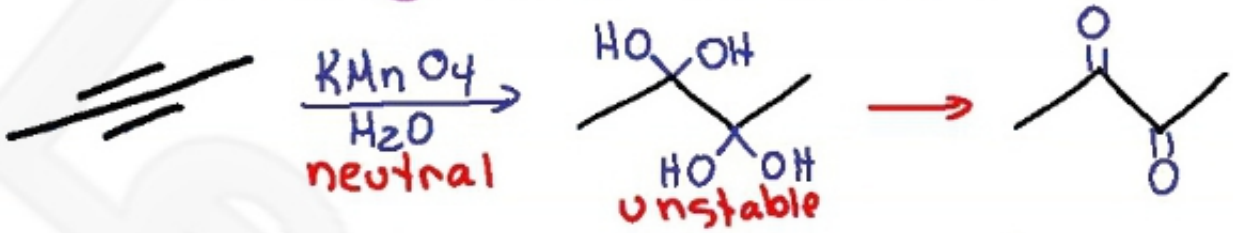
Halogenation

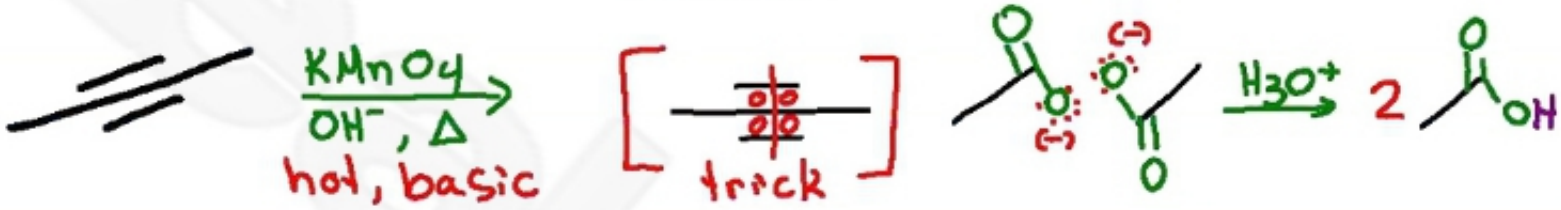


Ozonolysis

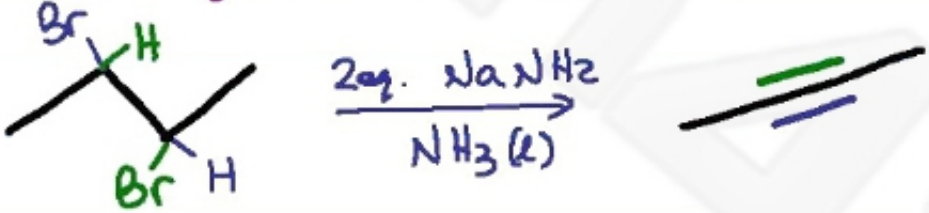


Permanganate Oxidation

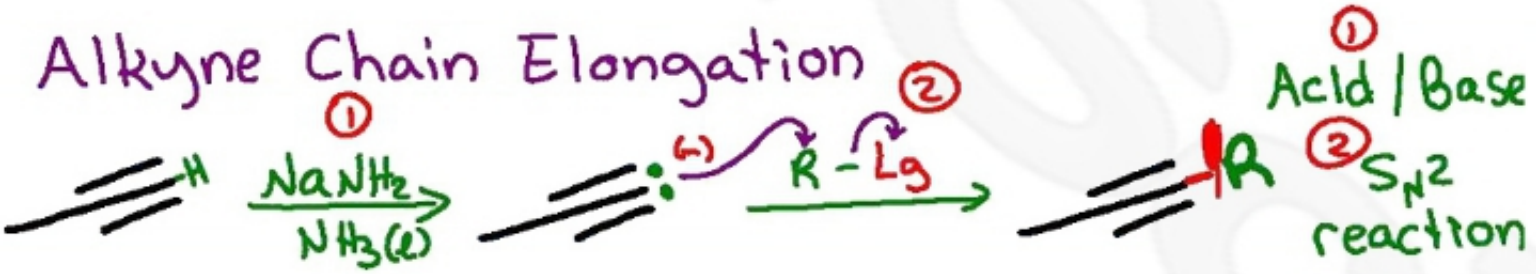




Alkyne Formation



Alkyne Chain Elongation



Notes Key:

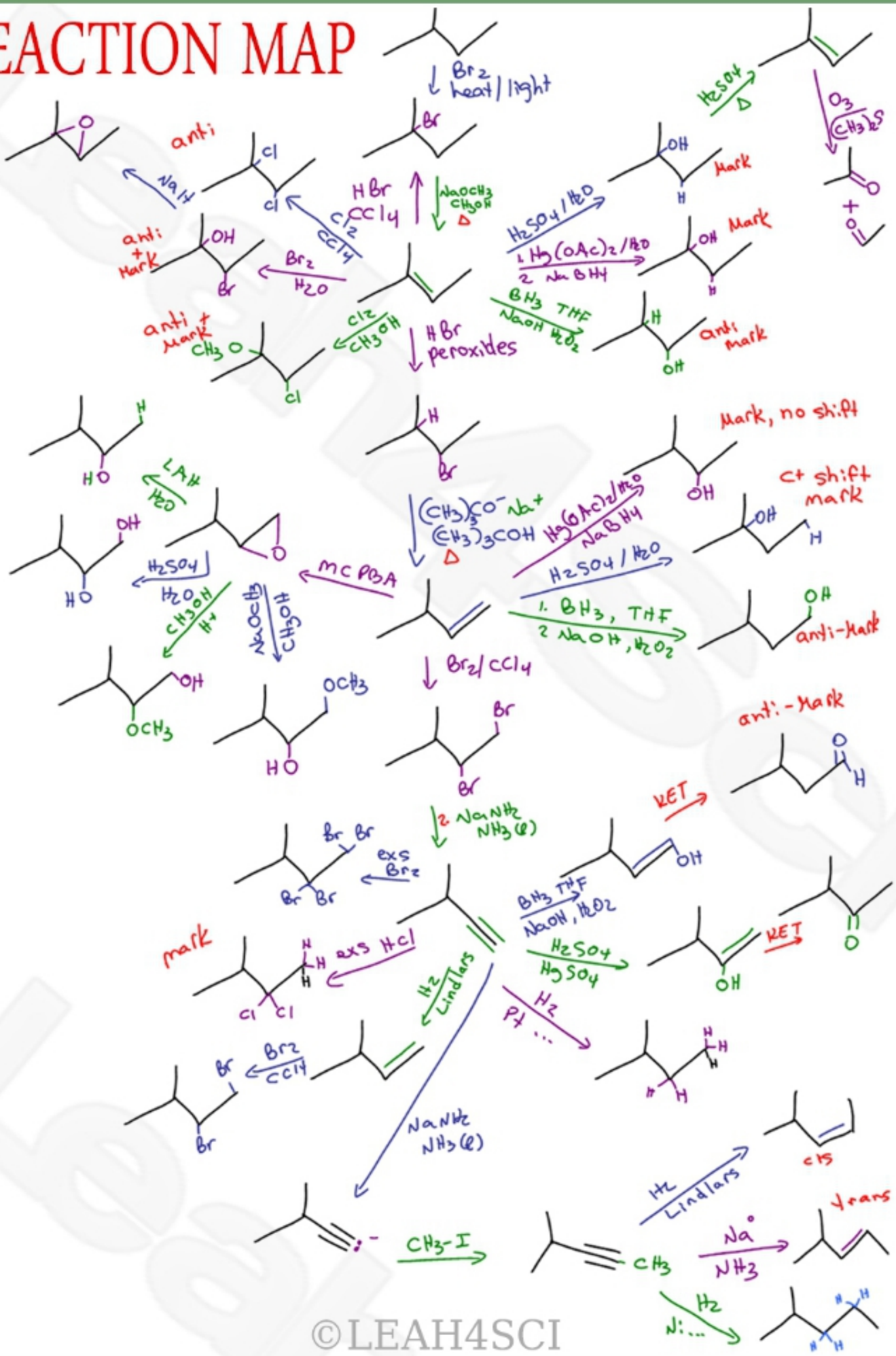
Mark = Markovnikov Anti-Mark = Anti-Markovnikov

Syn = Syn addition Anti = anti addition

Lg = Leaving group (S_N2) ex. Cl, Br, I

KET = Keto Enol Tautomerization

REACTION MAP



SN1 SN2 E1 E2

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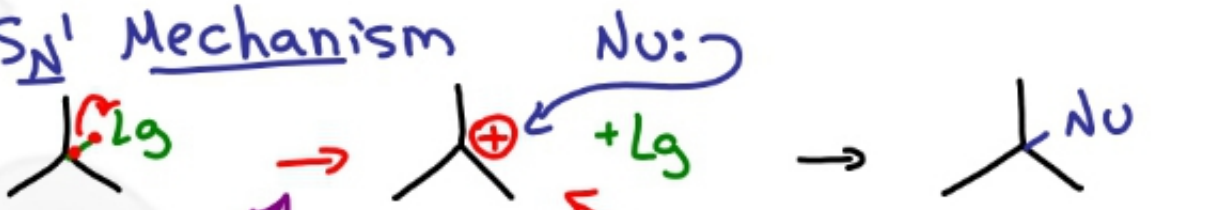
Complete orgo Substitution Elimination video series

Leah4Sci.com/Substitution-Elimination

S_N1 = Nucleophilic Substitution Unimolecular

$Rate_{S_N1} = k[alkyl]$ ← 1st order Rxn

S_N1 Mechanism



Slow 'Rate' Step

Key Intermediate C^+

S_N2 = Nucleophilic Substitution Bimolecular

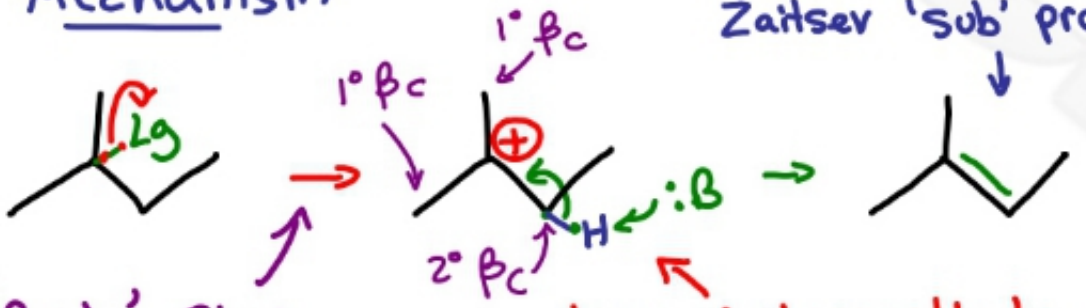
$Rate_{S_N2} = k[alkyl][Nu]$ ← 2nd order Rxn

S_N2 Mechanism

E_1 = β-Elimination Unimolecular

$Rate_{E_1} = k[alkyl]$ ← 1st order Rxn

E_1 Mechanism



Slow 'Rate' Step

Key Intermediate C^+

E_2 = β- Elimination Bimolecular

$Rate_{E_2} = k[alkyl][B]$ ← 2nd order Rxn

E_2 Mechanism

4-Part Checklist

- Alkyl chain
- Attacking Nu / B
- Leaving Group
- Solvent

Carbocation Stability

Benzyl > Allyl (↑ Resonance)

3° > 2° > 1° > Me (CH_3)

Alkyl Chain Analysis ← Position of Leaving Group

Methyl = only S_N2 ~~S_N1~~ ~~E_1~~ unstable C^+ ~~E_2~~ No β-H

Primary = S_N2 > E_2 ~~S_N1~~ ~~E_1~~ unstable C^+ (w neutral!)

Secondary = negative S_N1 S_N2 E_1 E_2 E_1 S_N1 = if weak Nu/B

if strong Nu/B $E_2 > S_N2$ protic, $S_N2 > E_2$ aprotic

Tertiary = S_N1 E_1 E_2 ~~S_N2~~ steric hindrance

S_N1 E_1 if weak Nu/B E_2 if strong B

Strength of attacking Nucleophile or Base

Negative = 'stronger'

ex CH_3O^-, OH^-, NH_2^-, 

Neutral = 'Weaker'

ex CH_3OH, H_2O, NH_3, 

Leaving Group Ability = Stability of anion

Lg = X^- $I^- > Br^- > Cl^- > F^-$ Lg ≠ X $H_2O > CH_3\text{-}\overset{\overset{O}{\|}}{C}\text{-}O^- > OH^- > OR^- > NH_2^-$

Solvent Type

Polar Protic = H-bonding (H on N, O, F)

ex. H_2O, CH_3OH, NH_3

Polar Aprotic = No H for H-bonding favors S_N2

ex. DMSO, DMF, Acetone, Acetonitrile

ELECTROPHILIC AROMATIC SUBSTITUTION

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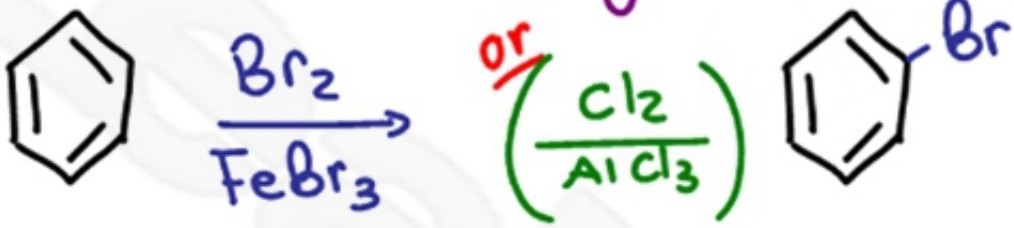
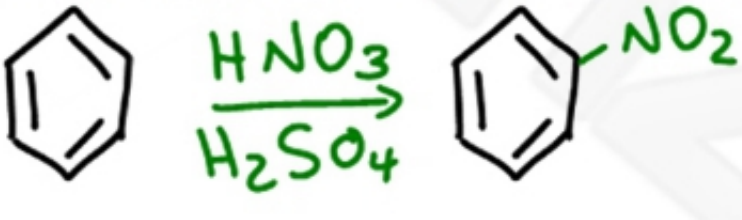
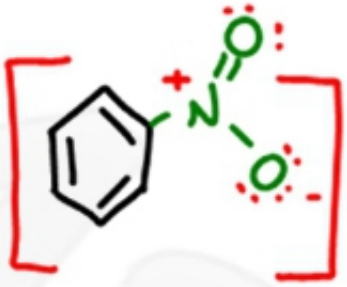
Aromatic Halogenation



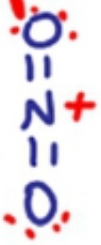
Super E+

Aromatic Nitration

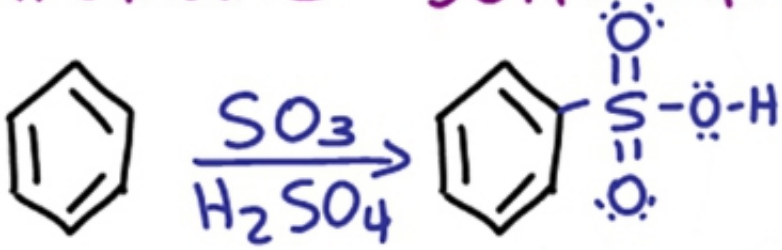




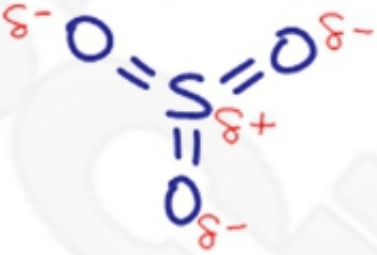
Super E+



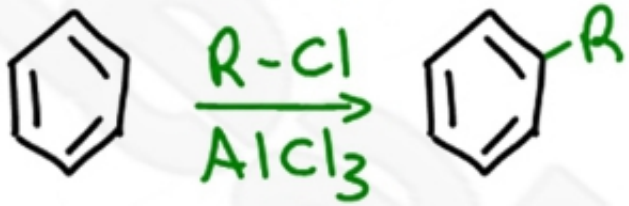
Aromatic Sulfonation



Super E+



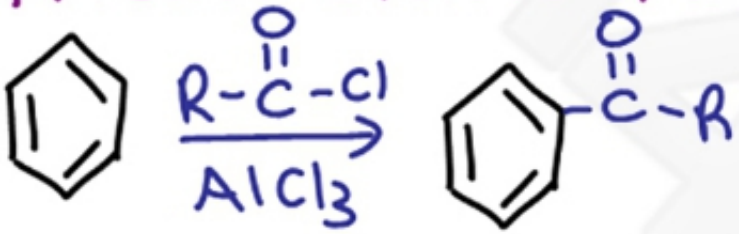
Friedel-Crafts Alkylation



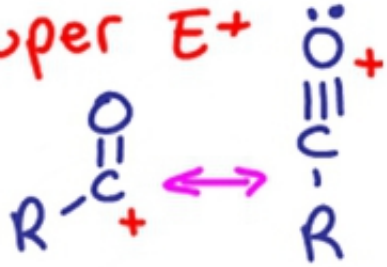
Super E+

R^+ carbocation

Friedel-Crafts Acylation



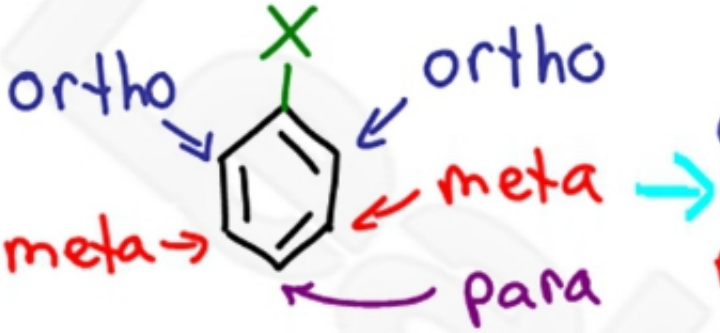
Super E+

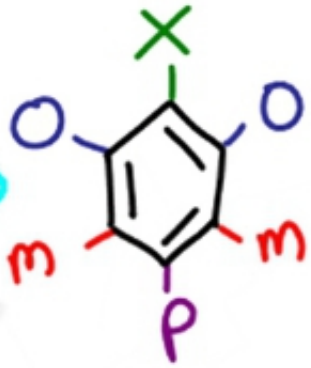


Sigma Complex Resonance

Substituted Benzene

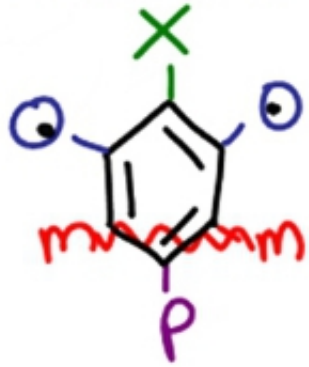
X = substituent





add
- eyes
- mouth
- tongue

O/M/P monster



Directing Effects

ortho / para = activating | exception | **meta = deactivating**

- $-NH_2$
- $-NHR$
- $-NR_2$
- $-OH$
- $-OR$
- $-\ddot{N}H-\overset{\overset{O}{\|}}{C}-R$
- $-\ddot{O}-\overset{\overset{O}{\|}}{C}-R$
- $-R$

exception:

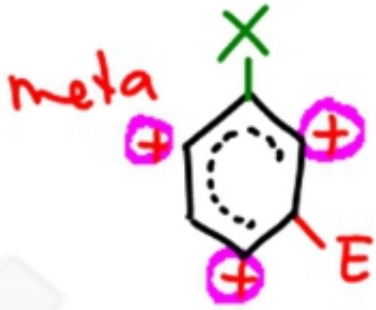
- $-F$
- $-Cl$
- $-Br$
- $-I$

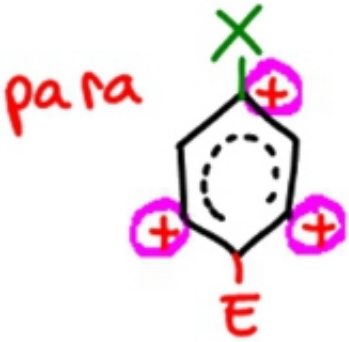
ortho para deactivating

- $-\overset{\overset{O}{\|}}{C}-H$
- $-\overset{\overset{O}{\|}}{C}-R$
- $-\overset{\overset{O}{\|}}{C}-OH$
- $-\overset{\overset{O}{\|}}{C}-N$
- $-\overset{\overset{O}{\|}}{S}(=O)-OH$
- $-C\equiv N$
- $-NO_2$
- $-\overset{+}{N}H_3$
- $-CF_3$
- $-CCl_3$

Strength ← | → Strength

Carbocation Resonance Trick





OXIDATION AND REDUCTION

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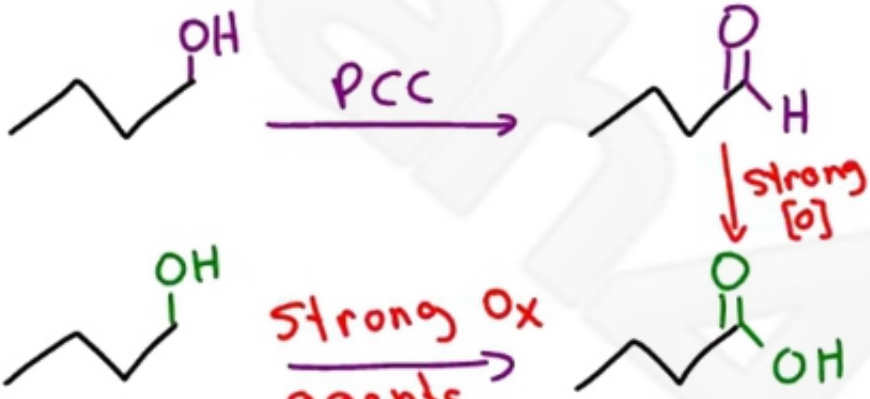
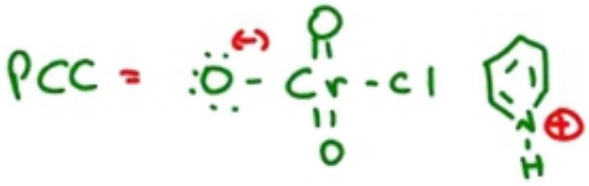
Oxidation = Gain O bonds, Lose H bonds





Strong ox agents

CrO_3, H_3O^+

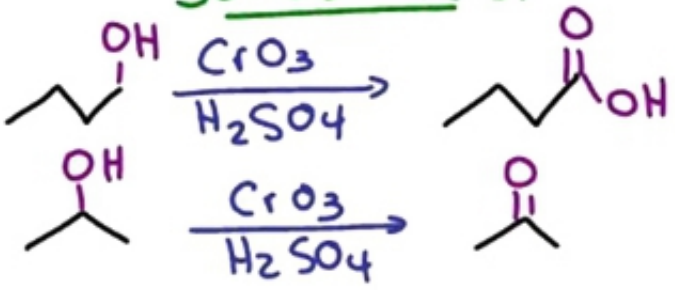
$Na_2Cr_2O_7$, H_2SO_4

H_2CrO_4

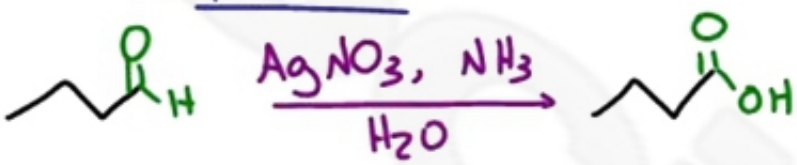
$K_2Cr_2O_7$, H_2SO_4

$KMnO_4$

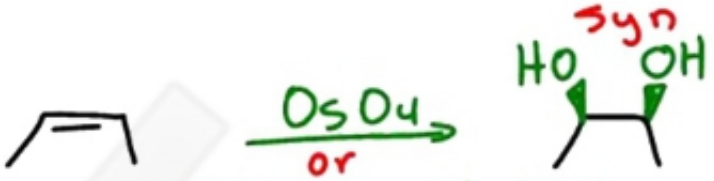
Jones Test

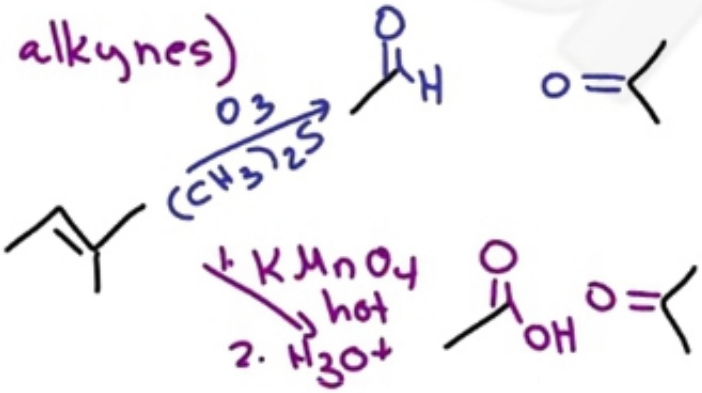


Tollens Test



Alkene Oxidation (also alkynes)



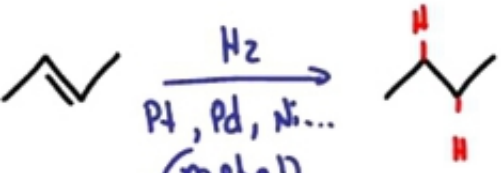


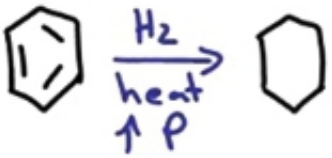
Side Chain Oxidation

only 1° & 2° get oxidized
3° = N/R

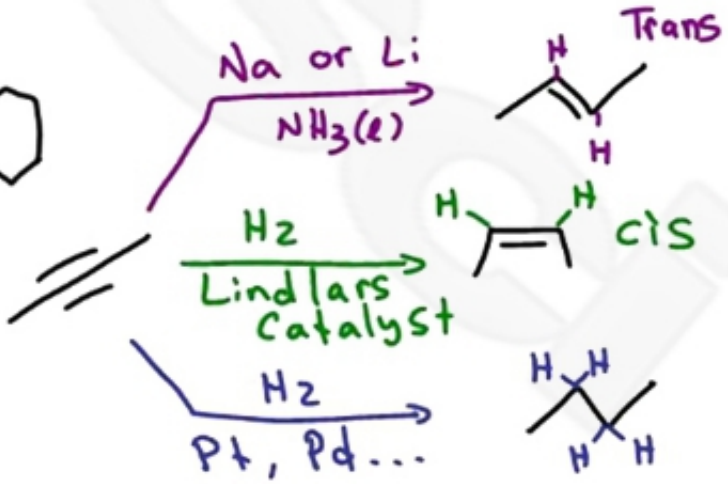
Reduction = Gain H bonds, Lose O bonds

Alkene Reduction

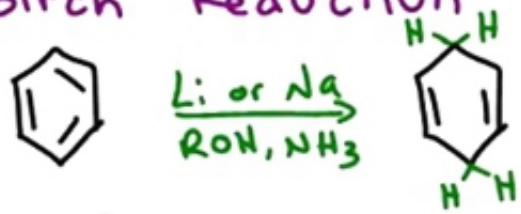




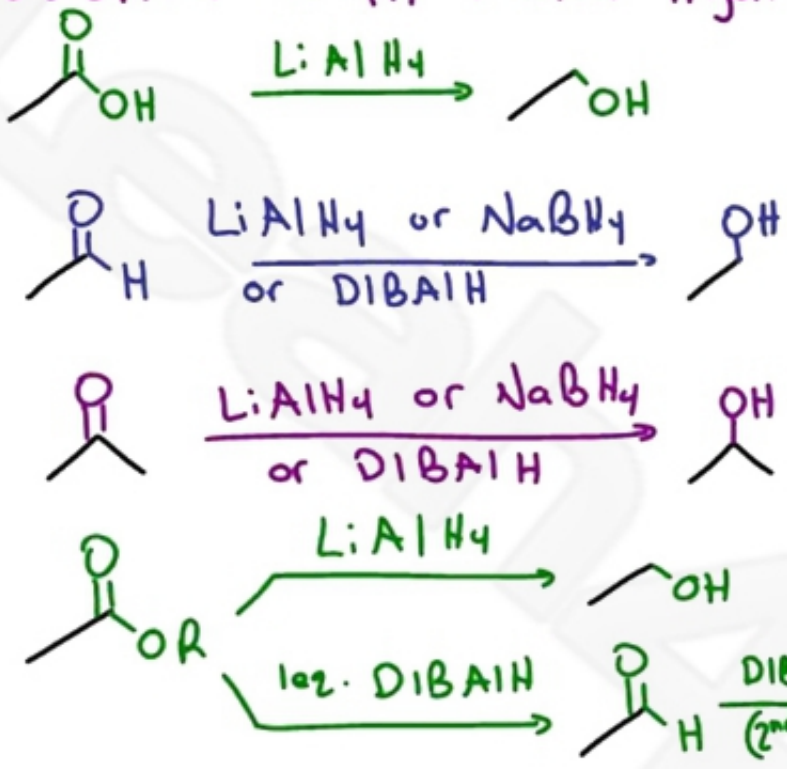
Alkyne Reduction



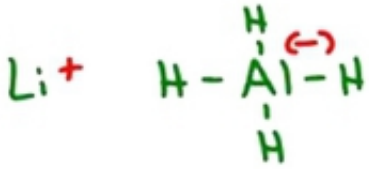
Birch Reduction



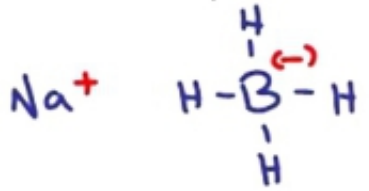
Reduction With Metal Hydrides



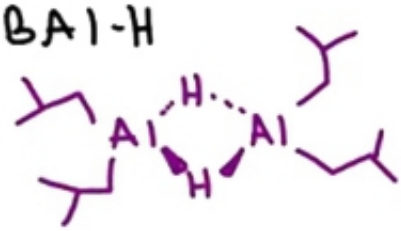
LiAlH4 = strong

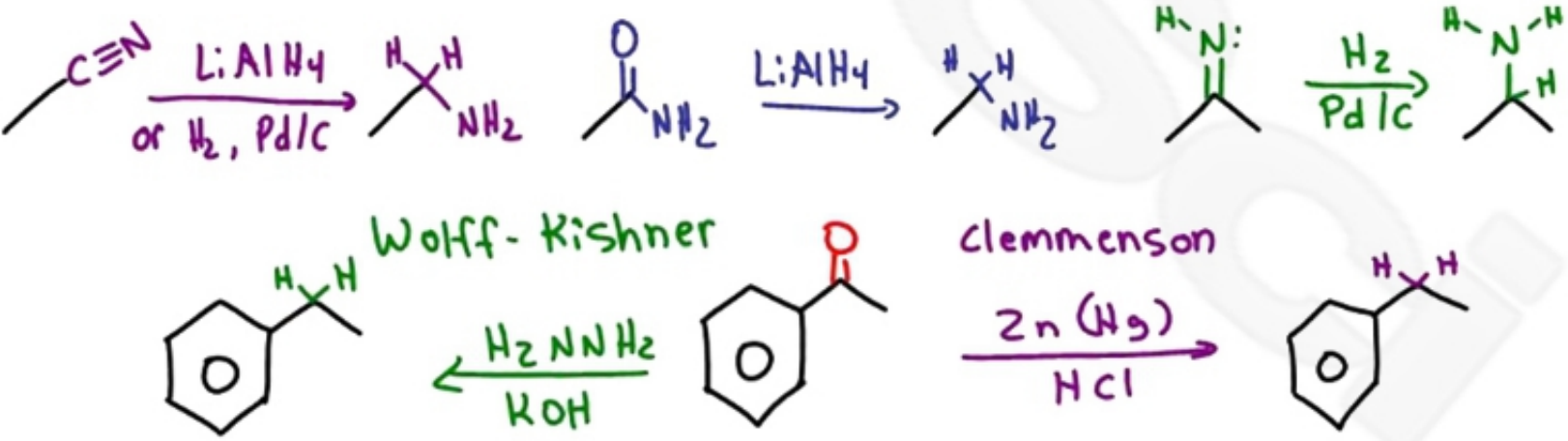


NaBH4 = weak



DIBAl-H




C≡N
LiAlH4
or H2, Pd/C
NH2
O
NH2
LiAlH4
NH2
H
N:
H2
Pd/C
H
N
H
H

Wolff-Kishner
H2NNH2
KOH
O
clemmenson
Zn(Hg)
HCl
H
H

CARBOXYLIC ACID DERIVATIVES

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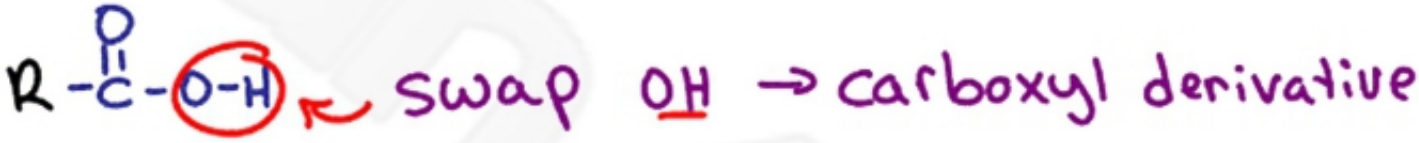
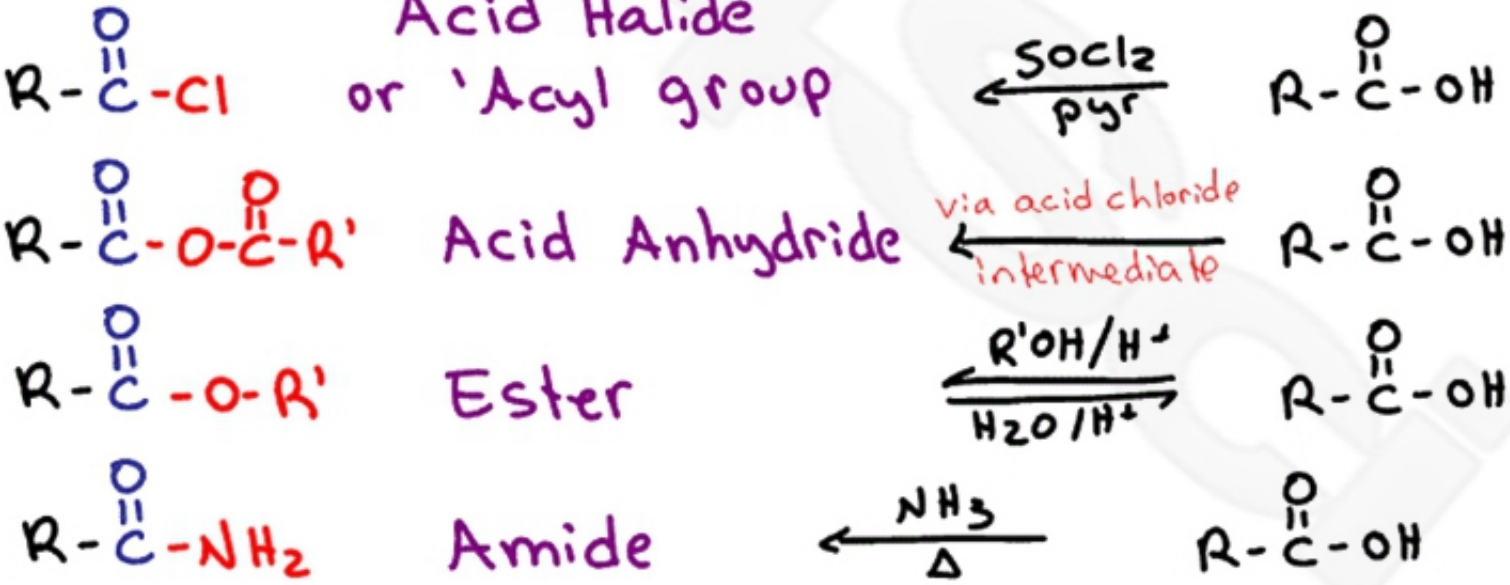
Carboxylic Acid

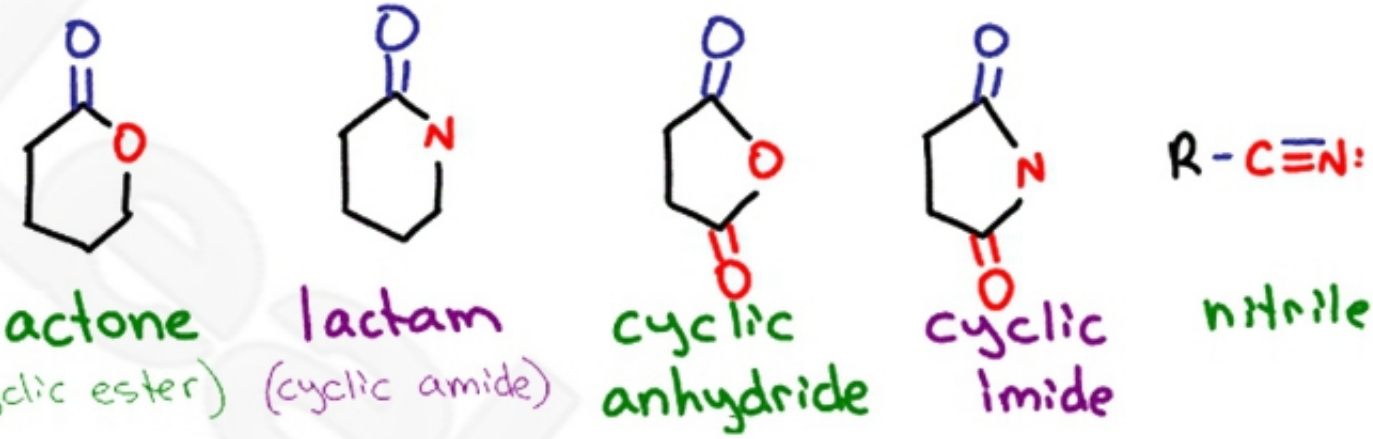


Common Derivatives

Reaction Reagents



Less Common Carboxyl Derivatives



Reactivity of Carboxyl Derivatives

Interconversion Between Derivatives