MCAT LSAT GMAT GRE **DAT** OAT PCAT

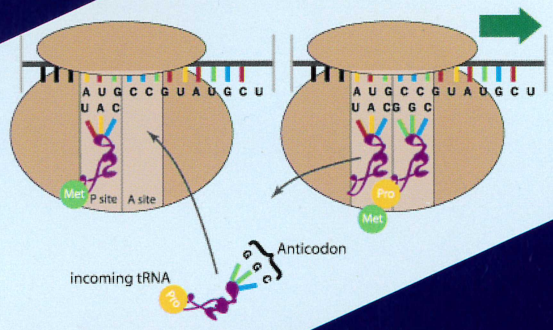
Kaplan Companion for the DAT®

The must-have science and formula guide for pre-dental students

NA using a DNA,

ntrons are cut out of hnRNA,

on ribosomes in the cytoplasm.



• **Post-translational modificati**
before the polypeptide h

berg
mating, no net

$pq + q^2 = 1$

ele q = freq. of rec. allele

= freq of dom homozygotes

$2pq$ = freq of heterozygotes

q^2 = freq of recessive homozygotes

CLASSICAL G

If both parents are Rr, the alleles separate to give a genotyp
ratio of 1:2:1 and a phenotypic ratio of 3:1.

w of independent assortment: Alleles of
sort independently in meiosis.

For two traits: AaBb parents
ab gametes.

The phenotypi

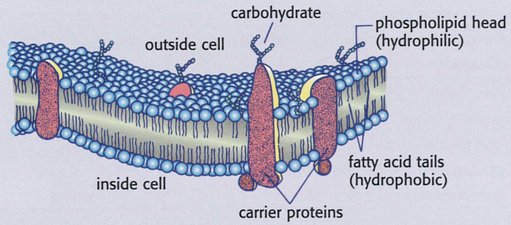
KAPLAN TEST PREP

DAT STUDY SHEET – BIOLOGY

THE CELL

FLUID MOSAIC MODEL AND MEMBRANE TRAFFIC

- Phospholipid bilayer with cholesterol and embedded proteins
- Exterior hydrophilic phosphoric acid region
- Interior hydrophobic fatty acid region



HOMEOSTASIS

HORMONAL REGULATION

Aldosterone

- stimulates Na^+ reabsorption and K^+ secretion, increasing water reabsorption, blood volume, and blood pressure.
- is secreted from adrenal cortex.
- is regulated by renin-angiotensin system.

ADH

- increases collecting duct's permeability to water to increase water reabsorption.
- is secreted from posterior pituitary with high [solute] in the blood.

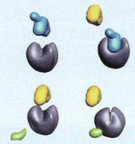
THE LIVER'S ROLES IN HOMEOSTASIS

1. Gluconeogenesis
2. Processing of nitrogenous wastes (urea)
3. Detoxification of wastes/chemicals/drugs
4. Storage of iron and vitamin B12
5. Synthesis of bile and blood proteins
6. Beta-oxidation of fatty acids to ketones
7. Interconversion of carbs, fat, and amino acids

ENZYMES

REGULATION

- **Allosteric**: Binding of an affector molecule at allosteric site.
- **Feedback inhibition**: End product inhibits an initial enzyme pathway.
- **Reversible inhibition**: Competitive inhibitors bind to active site; noncompetitive inhibitors to the allosteric site.



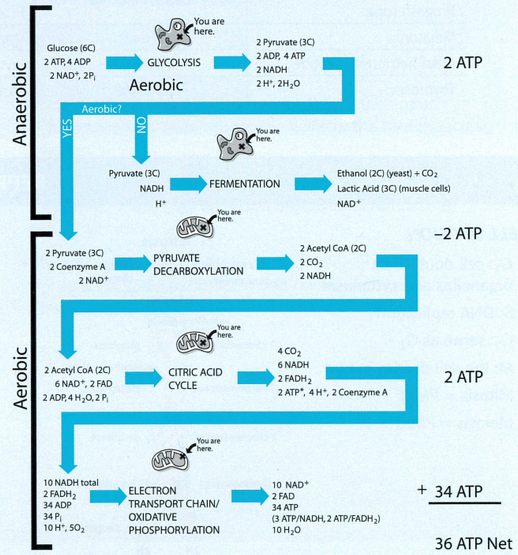
GLUCOSE CATABOLISM

Glycolysis occurs in the cell cytoplasm: $C_6H_{12}O_6 + 2ADP + 2P_i + 2NAD^+ \rightarrow 2Pyruvate + 2ATP + 2NADH + 2H^+ + 2H_2O$.

Fermentation occurs in anaerobic conditions. Pyruvate is converted into lactic acid (in muscle) or ethanol (in yeast).

Respiration occurs in aerobic conditions.

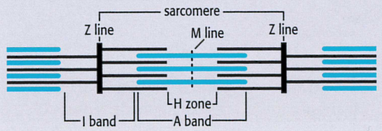
- **Pyruvate decarboxylation**: Pyruvate converted to acetyl CoA in the mitochondrial matrix.
- **Citric acid cycle**: Acetyl CoA enters; coenzymes exit.
- **Electron transport chain**: Coenzymes are oxidized, and energy is released as electrons are transferred from carrier to carrier.
- **Oxidative phosphorylation**: Electrochemical gradient caused by NADH and $FADH^2$ oxidation provides energy for ATP synthase to phosphorylate ADP into ATP.



MUSCULOSKELETAL SYSTEM

Sarcomere

- is the contractile unit of the fibers in skeletal muscle.
- contains thin actin and thick myosin filaments.



CONTRACTION

Initiation:

- Depolarization of a neuron leads to action potential.

BONE FORMATION AND REMODELLING

- Osteoblasts: Builds bone.
- Osteoclasts: Breaks down bone.
- Reformation: Inorganic ions are absorbed from the blood for use in bone.
- Degradation (Resorption): Inorganic ions are released into the blood.

ENDOCRINE SYSTEM

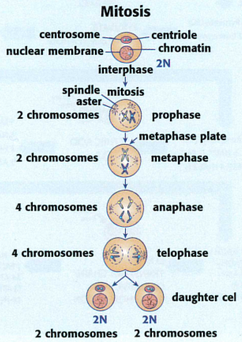
Direct hormones directly stimulate organs, tropic hormones stimulate other glands.
Mechanisms of hormone action: **Peptides** act via secondary messengers and **steroids** act via a hormone/receptor binding to DNA. Amino acid derivatives may do either.

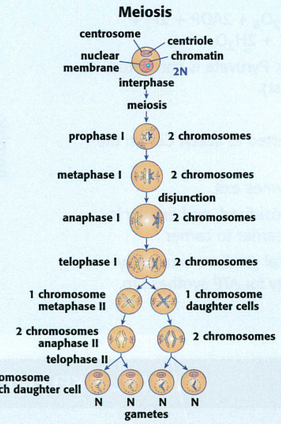
Hormone	Source	Action
Follicle-stimulating (FSH)	Anterior pituitary	Stimulates follicle maturation; spermatogenesis
Luteinizing (LH)		Stimulates ovulation; testosterone synthesis
Adrenocorticotropic (ACTH)		Stimulates adrenal cortex to make and secrete corticosteroids
Thyroid-stimulating (TSH)		Stimulates the thyroid to produce thyroid hormones
Prolactin		Stimulates milk production and secretion
Endorphins		Inhibit the perception of pain in the brain
Growth hormone		Stimulates bone and muscle growth/lipolysis
Oxytocin	Hypothalamus; stored in posterior pituitary	Stimulates uterine conteractions during labor, milk secretion during lactation
Vasopressin (ADH)		Stimulates water reabsorption in kidneys
Thyroid hormones (T_4, T_3)	Thyroid	Stimulate metabolic activity
Calcitonin		Decreases (tones down) blood calcium level
Parathyroid hormone	Parathyroid	Increases the blood calcium level
Glucocorticoids	Adrenal cortex	Increase blood glucose level and decrease protein synthesis
Mineralocorticoids		Increase water reabsorption in kidneys
Epinephrine, Norepinephrine	Adrenal medulla	Increases blood glucose level and heart rate
Glucagon	Pancreas	Stimulates conversion of glycogen to glucose in the liver, increases blood glucose
Insulin		Lowers blood glucose, increases glycogen stores
Somatostatin		Supresses secretion of glucagon and insulin
Testosterone	Testes	Maintains male secondary sexual characteristics
Estrogen	Ovary/Placenta	Maintains female secondary sexual characteristics
Progesterone		Promotes growth/maintenance of endometrium
Melatonin	Pineal	Unclear in humans
Atrial natriuretic peptide	Heart	Involved in osmoregulation and vasodilation
Thymosin	Thymus	Stimulates T lymphocyte development

REPRODUCTION

CELL DIVISION

- G_1: cell doubles its organelles and cytoplasm
- S: DNA replication
- G_2: same as G_1
- M: the cell divides in two
- Mitosis = PMAT
- Meiosis = PMAT × 2





SEXUAL REPRODUCTION

Meiosis I:

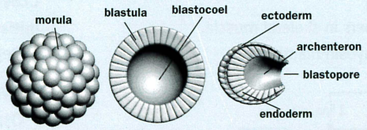
- Two pairs of sister chromatids form tetrads during prophase I.
- Crossing over leads to genetic recombination in prophase I.

Meiosis II:

- Identical to mitosis, but no replication.
- Meiosis occurs in **spermatogenesis** (sperm formation) and **oogenesis** (egg formation).

FOUR STAGES OF EARLY DEVELOPMENT

cleavage: mitotic divisions
implantation: embryo implants during blastulation
gastrulation: ectoderm, endoderm, and mesoderm form
neurulation: germ layers develop a nervous system



Ectoderm "Attract-o-derm"	Nervous system, epidermis, lens of eye, inner ear	**Endoderm** "Endernal" organs	Lining of digestive tract, lungs, liver and pancreas	**Mesoderm** "Means-o-derm"	Muscles, skeleton, circulatory system, gonads, kidney

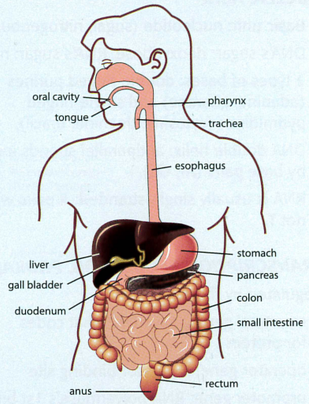
DIGESTION

CARBOHYDRATE DIGESTION

Enzyme	*Site of Production*	*Site of Function*	*Hydrolysis Reaction*
Salivary amylase (ptyalin)	Salivary glands	Mouth	Starch → maltose
Pancreatic amylase	Pancreas	Small Intestine	Starch → maltose
Maltase	Intestinal glands	Small Intestine	Maltose → 2 glucoses
Sucrase	Intestinal glands	Small Intestine	Sucrose → glucose, fructose
Lactase	Intestinal glands	Small Intestine	Lactose → glucose, galactose

PROTEIN DIGESTION

Enzyme	*Production Site*	*Function Site*	*Function*
Pepsin	Gastric glands (chief cells)	Stomach	Hydrolyzes specific peptide bonds
Trypsin	Pancreas	Small Intestine	Hydrolyzes specific peptide bonds Converts chymotrypsinogen to chymotrypsin
Chymotrypsin			Hydrolyzes specific peptide bonds
Carboxypeptidase			Hydrolyzes terminal peptide bond at carboxyl
Aminopeptidase	Intestinal glands		Hydrolyzes terminal peptide bond at amino
Dipeptidases			Hydrolyzes pairs of amino acids
Enterokinase			Converts trypsinogen to trypsin



IMMUNE SYSTEM

- The body distinguishes between "self" and "nonself" (antigens)

HUMORAL IMMUNITY (specific defense)

B lymphocytes

memory cells remember antigen, speed up secondary response

plasma cells make and release antibodies (**IgG, IgA, IgM, IgD, IgE**), which induce antigen phagocytosis

- **Active imumunity**: antibodies are produced during an immune response.
- **Passive immunity**: antibodies produced by one organism are transferred to another organism.

CELL-MEDIATED IMMUNITY

T lymphocytes

cytotoxic T cells destroy cells directly

suppressor cells regulate B and T cells to decrease anti-antigen activity

helper T cells activate B and T cells and macrophages by secreting lymphokines

memory cells

NONSPECIFIC IMMUNE RESPONSE

Includes skin, passages lined with cilia, macrophages, inflammatory response, and interferons (proteins that help prevent the spread of a virus).

LYMPHATIC SYSTEM

- lymph vessels meet at the thoracic duct in the upper chest and neck, draining into the veins of the cardiovascular system.
- vessels carry **lymph** (excess interstitial fluid), and capillaries (**lacteals**) collect fats by absorbing chylomicrons in the small intestine.
- **lymph nodes** are swellings along the vessels with phagocytic cells (leukocytes) that remove foreign particles from lymph.

CIRCULATION

BLOOD TYPING

Antigens are located on the surface of red blood cells

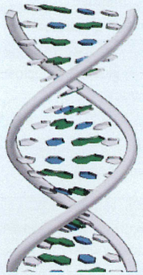
Blood type	RBC antigen	Antibodies	Donates to:	Receives From:
A	A	Anti-B	A, AB	A, O
B	B	Anti-A	B, AB	B, O
AB	A, B	None	AB only	All
O	None	Anti-A, B	All	O

Blood cells with Rh factor are Rh^+ and produce no antibody. Rh^- lack antigen and produce an antibody.

MOLECULAR GENETICS

NUCLEIC ACID

- Basic unit: nucleotide (sugar, nitrogenous base, phosphate)
- DNA's sugar: deoxyribose. RNA's sugar: ribose.
- 2 types of bases: double-ringed purines (adenine, guanine) and single-ringed pyrimidines (cytosine, thymine, uracil).
- DNA double helix: antiparallel strands joined by base pairs (AT, GC).
- RNA is usually single-stranded: A pairs with U, not T.



TRANSCRIPTION REGULATION, PROKARYOTES

Regulated by the **operon**:

- structural genes: have DNA that codes for protein
- operator gene: repressor binding site
- promoter gene: RNA polymerase's 1st binding site
- Inducible systems need an inducer for transcription to occur. Repressible systems need a corepressor to inhibit transcription.

MUTATIONS

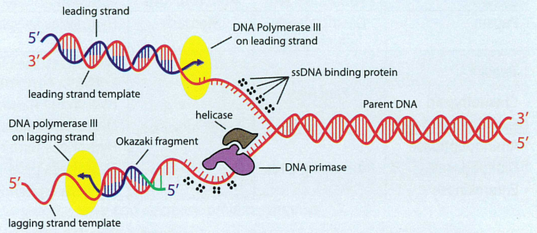
- **Point**: one nucleotide is substituted by another; they are silent if the sequence doesn't change.
- **Frameshift**: insertions or deletions shift reading frame. Protein doesn't form, or is nonfunctional.

VIRUSES

- acellular structures of double or single-stranded DNA or RNA in a protein coat.
- Lytic cycle: virus kills the host.
- Lysogenic cycle: virus enters host genome.

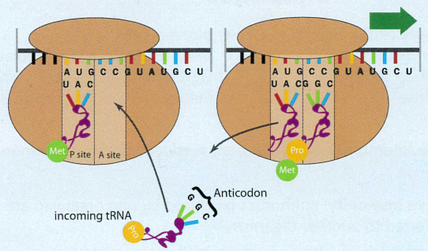
DNA REPLICATION

- **Semiconservative**: each new helix has an intact strand from the parent helix and a newly synthesized strand.



EUKARYOTIC PROTEIN SYNTHESIS

- **Transcription**: RNA polymerase synthesizes hnRNA using a DNA, "antisense strand" as a template.
- **Post-transcriptional processing**: introns are cut out of hnRNA, exons spliced to form mRNA.
- **Translation**: occurs on ribosomes in the cytoplasm.



- **Post-translational modifications**: (i.e., disulfide bonds) made before the polypeptide becomes a functional protein.

EVOLUTION

- When frequencies are stable, the population is in Hardy-Weinberg equilibrium: no mutations, large population, random mating, no net migration, and equal reproductive success.

$$p + q = 1;\ p^2 + 2pq + q^2 = 1$$

p = freq. of dom. allele q = freq. of rec. allele

p^2 = freq of dom homozygotes

$2pq$ = freq of heterozygotes

q^2 = freq of recessive homozygotes

CLASSICAL GENETICS

- If both parents are Rr, the alleles separate to give a genotypic ratio of 1:2:1 and a phenotypic ratio of 3:1.

Law of independent assortment: Alleles of unlinked genes assort independently in meiosis.

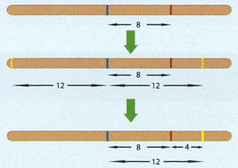
- For two traits: AaBb parents will produce AB, Ab, aB, and ab gametes.
- The phenotypic ratio for this cross is 9:3:3:1.

STATISTICAL CALCULATIONS

- The probability of producing a genotype that requires multiple events to occur equals the *product* of the probability of each event.
- The probability of producing a genotype that can be the result of multiple events equals the *sum* of each probability.

GENETIC MAPPING

- Crossing over during meiosis I can unlink genes (Prophase I).
- Genes are most likely unlinked when far apart.
- One map unit is 1% recombinant frequency.



Given Recombination frequencies

X and Y: 8%

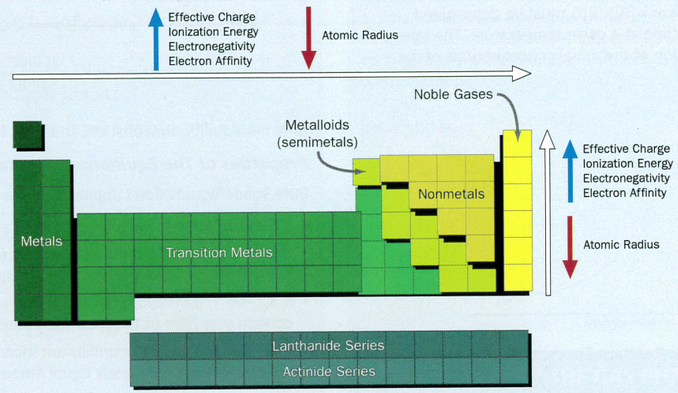
X and Z: 12%

Y and Z: 4%

INHERITED DISORDERS in PEDIGREES

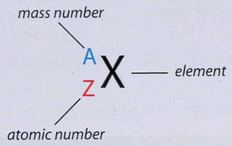
- Autosomal recessive: skips generations
- Autosomal dominant: appears in every generation
- X-linked (sex-linked): no male-to-male transmission, and more males are affected.

DAT STUDY SHEET – GENERAL CHEMISTRY



ATOMIC STRUCTURE

Atomic weight: the weight in grams of one mole (mol) of a given element and is expressed in terms of g/mol.



A **mole** is a unit used to count particles and is represented by **Avogadro's number**, 6.022×10^{23} particles.

$$\text{Moles} = \frac{\text{grams}}{\text{atomic or molecular weight}}$$

Isotopes: For a given element, multiple species of atoms with the same number of protons (same atomic number) but different numbers of neutrons (different mass numbers).

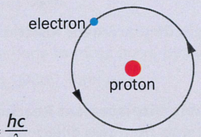
Planck's quantum theory: Energy emitted as electromagnetic radiation from matter exists in discrete bundles called quanta.

Bohr's Model of the Hydrogen Atom

Angular momentum $= \frac{nh}{2\eta}$

Energy of electron $= E = \frac{-RH}{n^2}$

Electromagnetic energy of photons $= E = \frac{hc}{\lambda}$



The group of hydrogen emission lines corresponding to transitions from upper levels $n > 2$ to $n = 2$ is known as the **Balmer series**, while the group corresponding to transitions between upper levels $n > 1$ to $n = 1$ is known as the **Lyman series.**

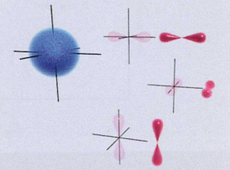
Absorption spectrum: Characteristic energy bands where electrons absorb energy.

Quantum Mechanical Model of Atoms

Heisenberg uncertainty principle: It is impossible to determine with perfect accuracy the momentum and the position of an electron simultaneously.

Quantum Numbers:

#	Character	Symbol	Value
1st	Shell	n	n
2nd	Subshell	l	From zero to n−1
3rd	Orbital	m_ℓ	Between l and −l
4th	Spin	m_s	½ or −½



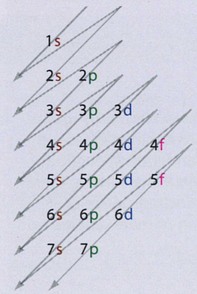
Principal Quantum Number (n): The larger the integer value of n, the higher the energy level and radius of the electron's orbit. The maximum number of electrons in energy level n is $2n^2$.

Azimuthal Quantum Number (l): Refers to subshells, or sublevels. The four subshells corresponding to $l = 0, 1, 2,$ and 3 are known as s, p, d and f, respectively. The maximum number of electrons that can exist within a subshell is given by the equation $4l+2$.

Magnetic Quantum Number (m_ℓ): This specifies the particular orbital within a subshell where an electron is highly likely to be found at a given point in time.

Spin Quantum Numb er (m_s): The spin of a particle is its intrinsic angular momentum and is a characteristic of a particle, like its charge.

Electron Configuration



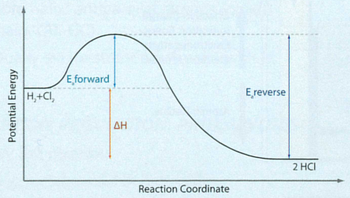
Hund's rule: Within a given subshell, orbitals are filled such that there are a maximum number of half-filled orbitals with parallel spins.

Valence electrons: Electrons of an atom that are in its outer energy shell or that are available for bonding.

KINETICS & EQUILIBRIUM

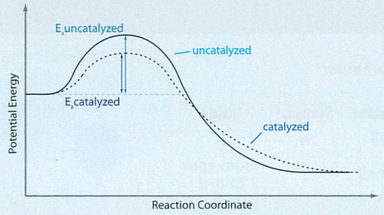
Experimental Determination of Rate Law: The values of k, x, and y in the rate law equation (rate = k $[A]^x$ $[B]^y$) must be determined experimentally for a given reaction at a given temperature. The rate is usually measured as a function of the initial concentrations of the reactants, A and B.

Efficiency of Reactions



Factors affecting reaction rates: Reactant Concentrations, Temperature, Medium, Catalysts

Catalysts are unique substances that increase reaction rate without being consumed; they do this by lowering the activation energy.



Law of Mass Action

$$a\,A + b\,B \rightleftharpoons c\,C + d\,D$$

$$K_c = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

K_c is the equilibrium constant. (c stands for concentration.)

Properties of The Equilibrium Constant

Pure solids/liquids don't appear in expression.

- K_{eq} is characteristic of a given system at a given temperature.
- If $K_{eq} >> 1$, an equilibrium mixture of reactants and products will contain very little of the reactants compared to the products.
- If $K_{eq} << 1$, an equilibrium mixture of reactants and products will contain very little of the products compared to the reactants.
- If K_{eq} is close to 1, an equilibrium mixture of products and reactants will contain approximately equal amounts of the two.

A + B ⇌ C + heat	
Will shift to **RIGHT**	Will shift to **LEFT**
1. if more A or B added	1. if more C added
2. if C taken away	2. if A or B taken away
3. if pressure applied or volume reduced (assuming A, B, and C are gases)	3 if pressure reduced or volume increased (assuming A, B, and C are gases)
4. if temperature reduced	4. if temperature increased

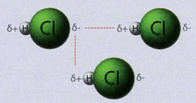
BONDING & CHEMICAL INTERACTIONS

Formal Charges

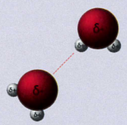
Formal charge = Valence electrons $-\frac{1}{2}N_{bonding} - N_{nonbonding}$

Intermolecular Forces

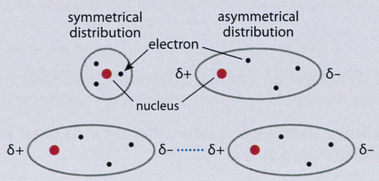
1. Dipole-Dipole Interactions: Polar molecules orient themselves such that the positive region of one molecule is close to the negative region of another molecule.



2. Hydrogen Bonding: The partial positive charge of the hydrogen atom interacts with the partial negative charge located on the electronegative atoms (F, O, N) of nearby molecules.



3. Dispersion Forces: The bonding electrons in covalent bonds may appear to be equally shared between two atoms, but at any particular point in time they will be located randomly throughout the orbital. This permits unequal sharing of electrons, causing rapid polarization and counter-polarization of the electron clouds of neighboring molecules, inducing the formation of more dipoles.



COMPOUNDS & STOICHIOMETRY

A **compound** is a pure substance that is composed of two or more elements in a fixed proportion.

A **mole** is the amount of a substance that contains the same number of particles that are found in a 12.000 g sample of carbon-12.

Combination Reactions: two or more reactants form one product.

$$S\,(s) + O_2\,(g) \rightarrow SO_2\,(g)$$

Decomposition Reactions: a compound breaks down into two or more substances, usually as a result of heating or electrolysis.

$$2HgO\,(s) \rightarrow 2Hg\,(l) + O_2\,(g)$$

Single Displacement Reactions: an atom (or ion) of one compound is replaced by an atom of another element.

$$Zn\,(s) + CuSO_4\,(aq) \rightarrow Cu\,(s) + ZnSO_4\,(aq)$$

Double Displacement Reactions: also called metathesis reactions, elements from two different compounds displace each other to form two new compounds.

$$CaCl_2\,(aq) + 2\,AgNO_3\,(aq) \rightarrow Ca(NO_3)_2\,(aq) + 2\,AgCl\,(s)$$

Net Ionic Equations: These types of equations are written showing only the species that actually participate in the reaction. So in the following equation,

$$Zn\,(s) + Cu^{2+}\,(aq) + SO_4^{2-}\,(aq) \rightarrow Cu\,(s) + Zn^{2+}\,(aq) + SO_4^{2-}\,(aq)$$

the spectator ion (SO_4^{2-}) does not take part in the overall reaction, but simply remains in solution throughout. The net ionic equation would be:

$$Zn\,(s) + Cu^{2+}\,(aq) \rightarrow Cu\,(s) + Zn^{2+}\,(aq)$$

Neutralization Reactions: These are a specific type of double displacements which occur when an acid reacts with a base to produce a solution of a salt and water:

$$HCl\,(aq) + NaOH\,(aq) \rightarrow NaCl\,(aq) + H_2O\,(l)$$

ACIDS AND BASES

Arrhenius Definition: An acid is a species that produces H+ (a proton) in an aqueous solution, and a base is a species that produces OH^- (a hydroxide ion).

Bronsted-Lowry Definition: An acid is a species that donates protons, while a base is a species that accepts protons.

Lewis Definition: An acid is an electron-pair acceptor, and a base is an electron-pair donor.

Properties of Acids and Bases

$$pH = -\log[H^+] = \log\left(\frac{1}{[H^+]}\right)$$

$$pH = -\log[OH^-] = \log\left(\frac{1}{[OH^-]}\right)$$

$$H_2O(l) \rightleftharpoons H^+\,(aq) + OH^-\,(aq)$$

$$K_w = [H^+][OH^-] = 10^{-14}$$

$$pH + pOH = 14$$

Weak Acids and Bases

$$HA(aq) + H_2O\,(l) \rightleftharpoons H_3O^+\,(aq) + A^-\,(aq)$$

$$K_a = \frac{[H_3O^+][A^-]}{[HA]}$$

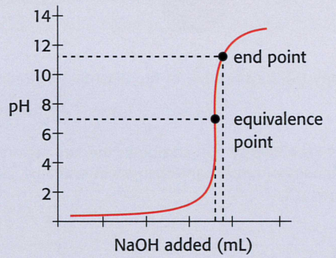
$$K_b = \frac{[B^+][OH^-]}{[BOH]}$$

Salt Formation: Acids and bases may react with each other, forming a salt and (often, but not always) water in a neutralization reaction.

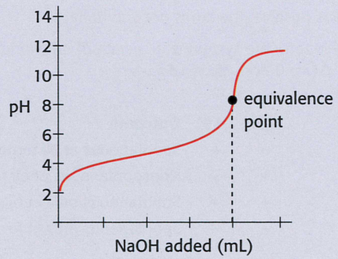
$$HA + BOH \rightarrow BA + H_2O$$

Titration and Buffers

Strong Acid and Strong Base



Weak Acid and Strong Base



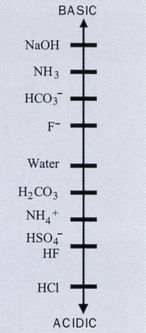
Titration is a procedure used to determine the molarity of an acid or base by reacting a known volume of a solution of unknown concentration with a known volume of a solution of known concentration.

ACIDS AND BASES *(cont.)*

Henderson-Hasselbalch equation is used to estimate the pH of a solution in the buffer region where the concentrations of the species and its conjugate are present in approximately equal concentrations.

$$pH = pK_a + \log\frac{[\text{conjugate base}]}{[\text{weak acid}]}$$

$$pOH = pK_b + \log\frac{[\text{conjugate acid}]}{[\text{weak base}]}$$



THE GAS PHASE

1 atm = 760 mm Hg = 760 torr

Do not confuse STP with standard conditions—the two standards involve different temperatures and are used for different purposes. STP (0°C or 273 K) is generally used for gas law calculations; standard conditions (25°C or 298 K) is used when measuring standard enthalpy, entropy, Gibbs free energy, and voltage.

Boyle's Law

$$PV = k \text{ or } P_1V_1 = P_2V_2$$

Law of Charles and Gay-Lussac

$$\frac{V}{T} = k \text{ or } \frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Avagadro's Principle

$$\frac{n}{V} = k \text{ or } \frac{n_1}{V_1} = \frac{n_2}{V_2}$$

Ideal Gas Law

$$PV = nRT$$

Deviations due to Pressure: As the pressure of a gas increases, the particles are pushed closer and closer together. At moderately high pressure a gas' volume is less than would be predicted by the ideal gas law, due to intermolecular attraction.

Deviations due to Temperature: As the temperature of a gas decreases, the average velocity of the gas molecules decreases, and the attractive intermolecular forces become increasingly significant. As the temperature of a gas is reduced, intermolecular attraction causes the gas to have a smaller volume than would be predicted.

SOLUTIONS

Units of Concentration

Percent Composition by Mass: $= \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 100\,(\%)$

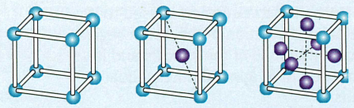
Mole Fraction: $\frac{\text{\# of mol of compound}}{\text{total \# of moles in system}}$

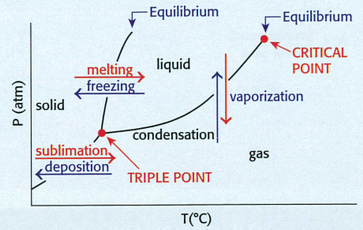
Molarity: $\frac{\text{\# of mol of solute}}{\text{liter of solution}}$

Molality: $\frac{\text{\# of mol of solute}}{\text{kg of solvent}}$

Normality: $\frac{\text{\# of gram equivalent weights of solute}}{\text{liter of solution}}$

PHASES & PHASE CHANGES





Colligative Properties: These are physical properties derived solely from the number of particles present, not the nature of those particles. These properties are usually associated with dilute solutions.

Freezing Point Depression

$\Delta T_f = K_f m$

Boiling Point Elevation

$\Delta T_b = K_b m$

Osmotic Pressure

$\prod = MRT$

Vapor-pressure Lowering (Raoult's Law)

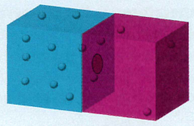
$P_A = X_A P^\circ_A$; $P_B = X_B P^\circ_B$

Solutions that obey Raoult's Law are called ideal solutions.

Graham's Law of Diffusion and Effusion

Diffusion: occurs when gas molecules diffuse through a mixture.

Effusion: is the flow of gas particles under pressure from one compartment to another through a small opening.



Effusion

Both diffusion and effusion have the same formula:

$$\frac{r_1}{r_2} = \left(\frac{MM_2}{MM_1}\right)^{\frac{1}{2}}$$

REDOX REACTIONS & ELECTROCHEMISTRY

Oxidation: loss of electrons

Reduction: gain of electrons

Oxidizing agent: causes another atom to undergo oxidation, and is itself reduced.

Reducing agent: causes another atom to be reduced, and is itself oxidized.

THERMOCHEMISTRY

Constant-volume and constant-pressure calorimetry: used to indicate conditions under which the heat changes are measured.

$q = mc\Delta T$, where q is the heat absorbed or released in a given process, m is the mass, c is the specific heat, and ΔT is the change in temperature.

States and State Functions: are described by the macroscopic properties of the system. These are properties whose magnitude depends only on the initial and final states of the system, and not on the path of the change.

Enthalpy (H): is used to express heat changes at constant pressure.

Standard Heat of Formation (ΔH°_f): the enthalpy change that would occur if one mole of a compound were formed directly from its elements in their standard states.

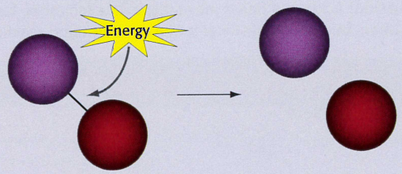
Standard Heat of Reaction (ΔH°_{rxn}): the hypothetical enthalpy change that would occur if the reaction were carried out under standard conditions.

ΔH°_{rxn} = (sum of ΔH°_{rxn} of products) – (sum of ΔH°_{rxn} of reactants)

Hess's Law: states that enthalpies of reactions are additive.

The reverse of any reaction has an enthalpy of the same magnitude as that of the forward reaction, but its sign is opposite.

Bond Dissociation Energy: an average of the energy required to break a particular type of bond in one mole of gaseous molecules:



Entropy (S) the measure of the disorder, or randomness, of a system.

$\Delta S_{universe} = \Delta S_{system} + \Delta S_{surroundings}$

Gibbs Free Energy (G): combines the two factors which affect the spontaneity of a reaction—changes in enthalpy, ΔH, and changes in entropy, ΔS.

$\Delta G = \Delta H - T\Delta S$

if ΔG is negative, the rxn is spontaneous

if ΔG is positive, the rxn is not spontaneous

if ΔG is zero, the system is in a state of equilibrium; thus, $\Delta G = 0$ and $\Delta H = T\Delta S$

ΔH	ΔS	Outcome
–	+	Spontaneous at all temps.
+	–	Nonspontaneous at all temps.
+	+	Spontaneous only at high temps.
–	–	Spontaneous only at low temps.

Reaction Quotient (Q): Once a reaction commences, the standard state conditions no longer hold. For the reaction,

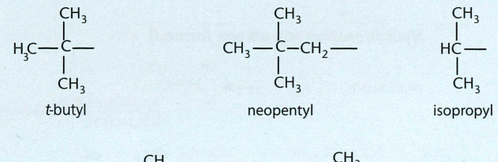
$a\,A + b\,B \rightleftharpoons c\,C + d\,D$

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}$$

DAT STUDY SHEET – ORGANIC CHEMISTRY

NOMENCLATURE

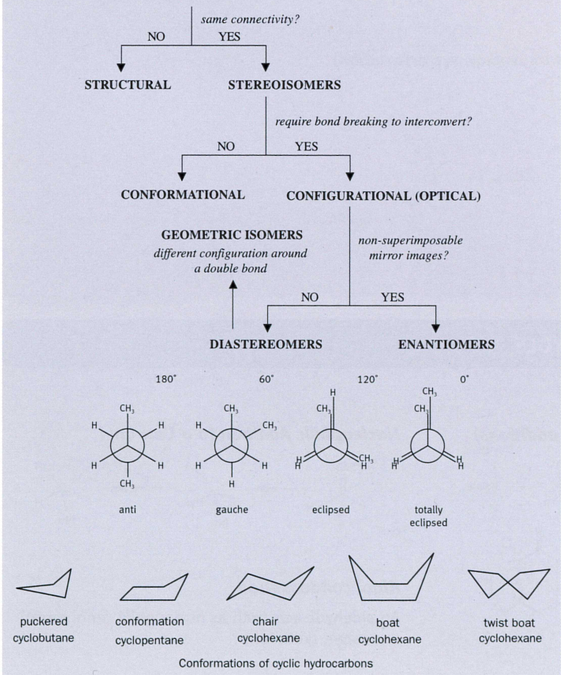
1. Find the longest carbon chain containing the principle functional group (highest priority groups are generally more oxidized).
2. Number the carbon chain so that the principle functional group gets lowest number (1).
3. Proceed to number the chain so that the lowest set of numbers is obtained for the substituents.
4. Name the substituents and assign each a number.
5. Complete the name by listing substituents in alphabetical order; place commas between numbers and dashes between numbers and words.



Functional Group	Suffix
Carboxylic Acid	-oic acid
Ester	-oate
Acyl halide	-oyl halide
Amide	-amide
Nitrile/Cyanide	-nitrile
Aldehyde	-al

Functional Group	Suffix
Ketone	-one
Thiol	-thiol
Alcohol	-ol
Amine	-amine
Imine	-imine
Ether	-ether

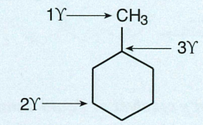
ISOMERS



BONDING

Bond order	single	double	triple
Bond type	sigma	sigma pi	sigma 2 pi
Hybridization	sp^3	sp^2	sp
Angles	109.5°	120°	180°
Example	C–C	C=C	C≡C

ALKANES



Free radical halogenation

- Initiation
- Propagation
- Termination

Combustion

$C_3H_8 + 5O_2 \rightarrow 3CO_2 + 4H_20 + \text{heat}$

Nucleophilicity and basicity

$RO^- > HO^- > RCO_2^- > ROH > H_2O$

Nucleophilicity, size, and polarity

$CN^- > I^- > RO^- > HO^- > Br > Cl^- > F^- > H_2O$

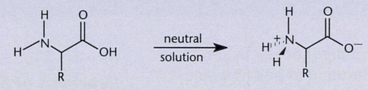
Leaving groups (weak bases best)

$I^- > Br^- > Cl^- > F^-$

S_N1	S_N2
2 steps	1 step
Favored in polar protic solvents.	Favored in polar aprotic solvents.
3° > 2° > 1° > methyl.	Methyl > 1° > 2° > 3°.
Rate = k[RX].	Rate = k[*Nu*][*RX*].
Racemic products	Optically active and inverted products
Strong nucleophile not required.	Favored with strong nucleophile.

AMINO ACIDS, PEPTIDES, & PROTEINS

Amino acids have four substituents: amine group, carboxyl group, hydrogen, and R group. Amino acids are **amphoteric**—they can act as either acids or bases and often take the form of **zwitterions** (dipolar ions).



Structure

Primary: Sequence of amino acids

Secondary: α-helix, β-pleated sheet

Tertiary: Disulfide bridges, hydrophobic/hydrophilic interactions

Quaternary: Arrangement of polypeptides

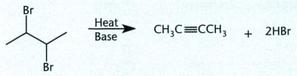
Henderson–Hasselbalch Equation

$pH = pK_a + \log [\text{conj. base}]/[\text{conj. acid}]$

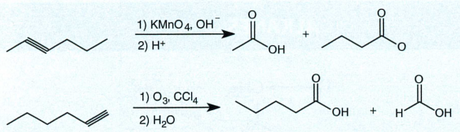
ALKYNES

Alkynes have a terminal hydrogen that is appreciably more acidic than hydrogens on alkanes and alkenes.

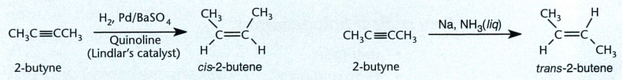
Synthesis via double elimination of geminal or vicinal dihalide



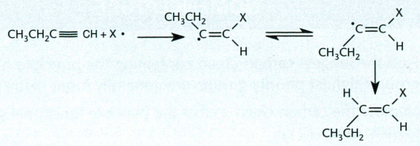
Oxidation with $KMnO_4$, O_3



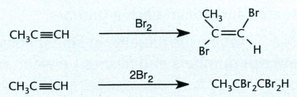
Reduction with Lindlar's catalyst or liquid ammonia



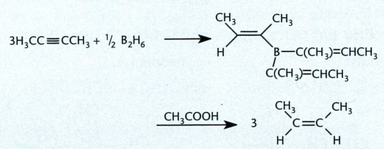
Free radical addition



Electrophilic addition (anti orientation)



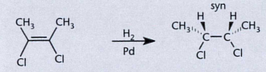
Hydroboration (cis alkene formed)



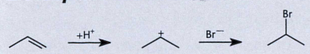
ALKENES

Cis isomers have higher boiling points than *trans* isomers due to their net dipole moment. *Trans* isomers have higher melting points than *cis* isomers due to more effective arrangement (more efficient packing).

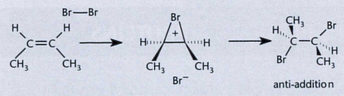
Catalytic Reduction



Electrophilic Addition of HX

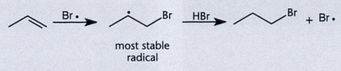


Electrophilic Addition of X_2

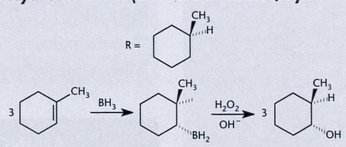


Electrophilic Addition of H_2O

Free Radical Addition (anti-Markovnikov)

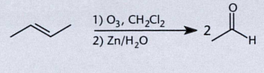


Hydroboration (anti-Markovnikov, syn orientation)



Oxidation with $KMnO_4$

Oxidation with O_3



Oxidation with O_2

ALDEHYDES

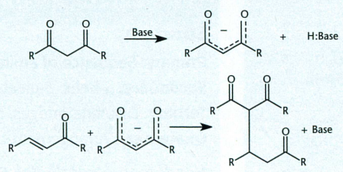
The dipole moment of aldehydes causes an elevation of boiling point, but not as high as alcohols since there is no hydrogen bonding.

Synthesis

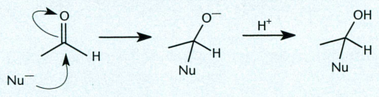
- Oxidation of primary alcohols
- Ozonolysis of alkenes
- Friedel-Crafts acylation

Reactions

Reactions of Enols (Michael additions)



Nucleophilic Addition to a Carbonyl



Aldol condensation

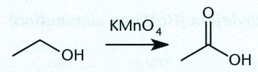
An aldehyde acts both as nucleophile (enol form) and target (keto form).

CARBOXYLIC ACIDS

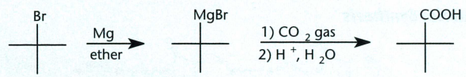
Carboxylic acids have pKa's of around 4.5 due to resonance stabilization of the conjugate base. Electronegative atoms increase acidity with inductive effects. Boiling point is higher than alcohols because of the ability to form two hydrogen bonds.

Synthesis

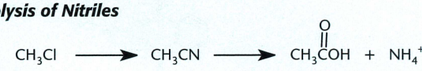
Oxidation of Primary Alcohols with $KMnO_4$



Organometallic Reagents with CO_2 (Grignard)

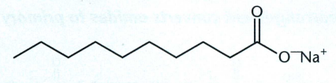


Hydrolysis of Nitriles



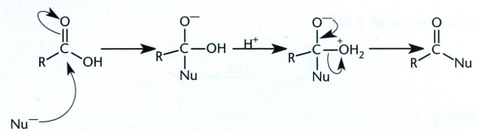
Reactions

Formation of soap by reacting carboxylic acids with NaOH; arrange in micelles.

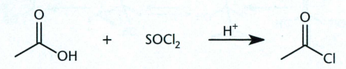


Nucleophilic Acyl Substitution

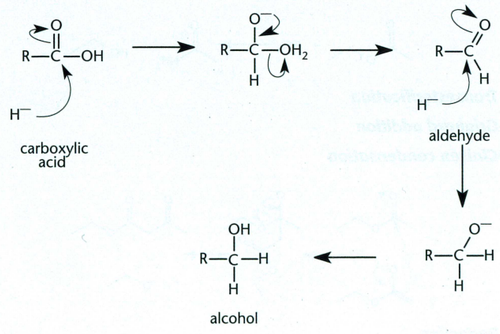
Ester formation



Acyl halide formation



Reduction to alcohols



ALCOHOLS

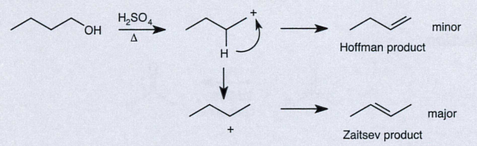
- Higher boiling points than alkanes
- Weakly acidic hydroxyl hydrogen

Synthesis

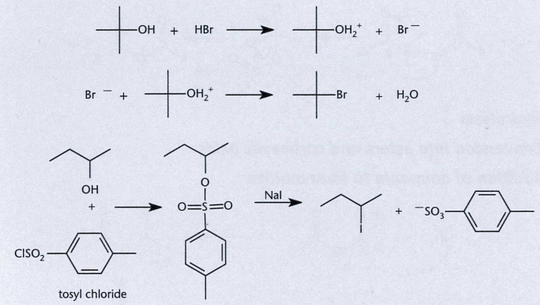
- Addition of water to double bonds
- S_N1 and S_N2 reactions
- Reduction of carboxylic acids, aldehydes, ketones, and esters
  - Aldehydes and ketones with $NaBH_4$
  - Esters and carboxylic acids with $LiAlH_4$

Reactions

E1 dehydration reactions in strongly acidic solutions

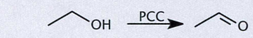


Substitution reactions after protonation or leaving group conversion

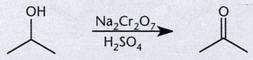


Oxidation

- PCC takes a primary alcohol to an aldehyde.

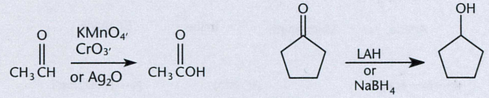


- Jones's reagent, $KMnO_4$, and alkali dichromate salts will convert secondary alcohols to ketones and primary alcohols to carboxylic acids.

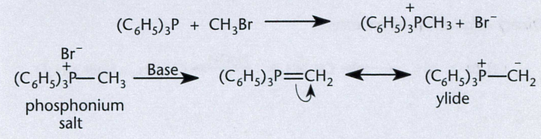


- Tertiary alcohols cannot be oxidized without breaking a carbon-to-carbon bond.

Oxidation and Reduction



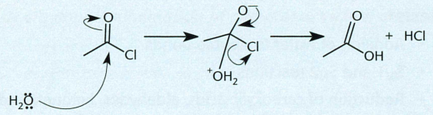
Wittig Reaction



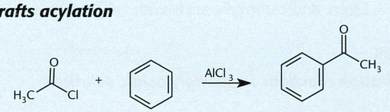
CARBOXLIC ACID DERIVATIVES

Acyl halides

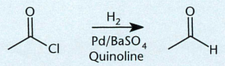
Nucleophilic acyl substitution



Friedel–Crafts acylation

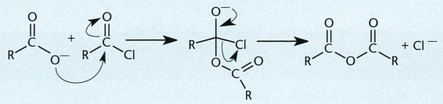


Reduction



Anhydrides

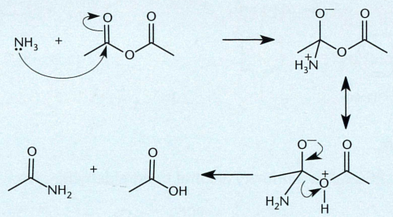
Synthesis via reaction of carboxylic acid with an acid chloride



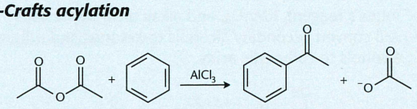
Hydrolysis

Conversion into esters and carboxylic acids

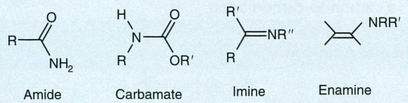
Addition of ammonia to form amides

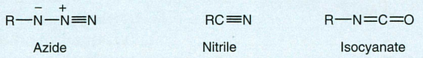


Friedel–Crafts acylation

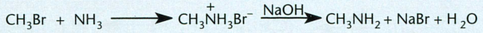


Amines & Nitrogen Containing Compounds

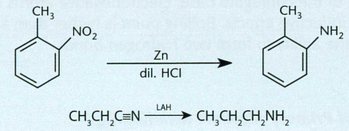




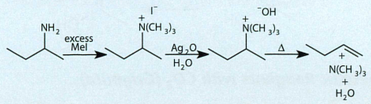
Direct alkylation of ammonia



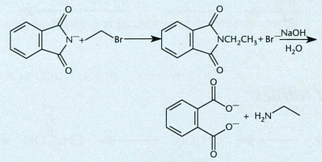
Reduction from nitro compounds, nitriles, imines, and amides



Exhaustive methylation (Hoffman elimination)



Gabriel Synthesis

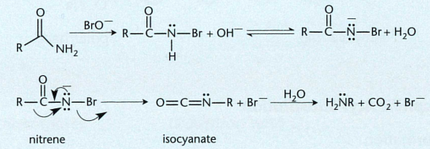


Amides

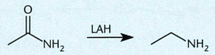
Synthesis via reaction of acid chlorides with amines or acid anhydrides with ammonia

Hydrolysis

Hoffman rearrangement converts amides to primary amines

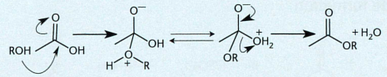


Reduction with LAH



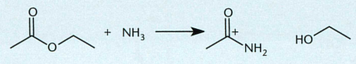
Esters

Synthesis via condensation of carboxylic acids and alcohols



Hydrolysis in acid or base

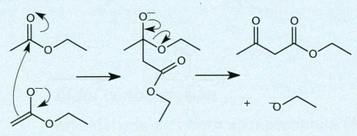
Conversion to amides



Transesterification

Grignard addition

Claisen condensation



Reduction

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