Materials & Molecules summary

Part 1: materials science

Lecture 1

structure-property relations
materials → molecules → atoms
atomic scale → interatomic bonding

1. Interatomic bonding

atoms bond to lower their energy
electron configuration → noble gas, fully filled shells
valence electrons → extra electrons in outer shell present compared to previous noble gas
electronegativity: tendency of an atom to attract/repel electrons

↑ EN → accept electrons, right pd
↓ EN → give up electrons, left in pd

chemical bonds in covalent valence state
- ionic → atoms that donated electrons (+) & accepted electrons (−)
- metallic ↳ experience strong mutual Coulomb attraction
- covalent ↳ if interatomic distance is too small, strong repulsion occurs
  ↳ metal & non-metal high difference in electronegativity

ionic bonds form crystals → stable

covalent bonds → small difference electronegativity
↳ share common electron pairs
coordination number & bond angle are determined by orbital geometry
diamond covalent sp^3 bonding of C
graphite sp^2 bonding, vdW bonding between planes

metallic bonds
valence electrons are delocalized from the atoms and move freely through the metal
combinations metal atoms

Van der Waals bonding → weak in comparison between dipoles

bonding	metallic	covalent	ionic	v.d. Waals + covalent
material	metal	ceramic / semiconductor	ceramic	polymer
electrical conduction	high	low*	low*	low*
thermal conduction	high	low*	low	low
ductility	high*	low	low	high
hardness	low*	high	high	low
melting point	low - high	high	high	low*

covalent bonding → column IV or III-V or II-VI

Lecture 2

2. Mechanical properties

to know when material deform elastically, plastically & finally fracture

stress → $\sigma = \frac{F}{A}$

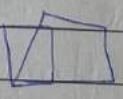
strain → $\varepsilon = \frac{l - l_0}{l_0}$ relative change in length dmsl

normal stress σ $F \perp A$

shear stress τ $F \parallel A$

tensile strain $\varepsilon_{\parallel} = \frac{\delta}{L_0}$

compressive " $\varepsilon_{\perp} = \frac{-\delta_L}{W_0}$

shear strain $\gamma = \tan(\theta)$ 

permanent strain, material deformed, atoms have slided in respect to each other → plastic

crystal planes slide & don't go back

elastic spring back

if dislocations can move through a material easily → soft, ductile & not strong material

metals can be made harder & stronger by introducing obstacles for dislocation movement
everything that reduces dislocation mobility leads to a stronger & harder, but also more brittle material

obstacles dislocation movement:
1. other dislocations (repulsion & attraction)
   cold work (hardening) → higher dislocation density, increase in (yield) strength → more brittle

2. substitutional atoms → alloys
   → prefer to be in compressive region around dislocation and hinder further slip of dislocation

3. grain boundaries
   by misorientation/disordered space between the grains, further slip of dislocations is strongly hampered

4. precipitates
   many small particles in alloys

strength alone is of no use, ductility is essential
best is to start with ductile material → pure metal
then introduce obstacles for dislocation movement
optimize obstacles (density) → optimize mechanical properties

recrystallization: decrease in dislocation energy in crystals
grain growth: decrease in interface energy

4 principles strengthen metals
1. cold work
2. grain refinement
3. solid solution hardening
4. precipitation hardening

Lecture 4
4 Fracture

1. stress concentration
2. fatigue
3. creep
(4. corrosion)

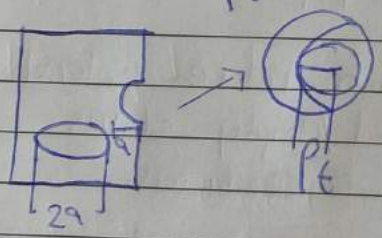
types of fracture:
- brittle: small (permanent) strain, almost no necking
  smooth fracture surface ⊥ to loading direction (tension)
  occurs intercrystalline (between grains) + intercrystalline (through grains)
- ductile: high (permanent) strain, necking
  rough fracture surface 45° to loading direction (tensile)

brittle:
intra-granular → smallest fracture surface costs least energy
inter-granular → larger fracture surface only possible due to grain boundary weakening

1. Due to stress concentrations the nominal stress level can be strongly amplified at local spots with imperfections
→ a crack can initiate, grow & fracture a material at a nominal stress level considered safe!

$$\sigma_m = 2\sigma_0\sqrt{\frac{a}{\rho_t}}$$

so ρ_t is radius of circle that fits in imperfection



ductile material → sharp crack starts to propagate & plastically deforms
↳ crack tip blunts → stress concentrations decrease, generally stops further movement of the crack

brittle material → crack remains sharp (no plastic deformation)
↳ stress concentration doesn't decrease
crack will grow catastrophically

plasticity is essential!

2. When applying cyclic load (mean stress, stress amplitud and frecuency of stress cycle), a material can still fail for below yield strength after large amount of stress cycles

materials with fatigue limit → always safe
without → finite lifetime

3. With a static load at relatively high temperatures a material loaded for below yield strength can break in time due to continious straining

Lecture 5

5. electrical properties of materials

$V = IR$ ohm's law

$\rho = \frac{(R)A}{\ell}$ resistivity A → cross sectional area, ℓ → wire length

$\sigma = \frac{1}{\rho}$ conductivity

$\sigma = n|e|\mu_e$ n → number of free electrons per unit volume

in solids & most liquids atoms interact and then degenerate states of overlapping electron energy levels develpop into continious bands

band structure determines n, varies much between materials
metals → without bandgap between filled/empty states
many free electrons → conductors

large bandgap low number free electrons

ionic (solid) & covalent bonds → insulators / semiconductors

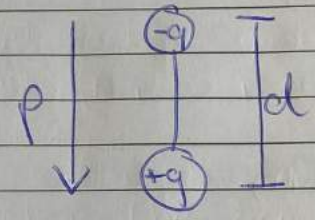
conductivity of metals ↓ temperature ↑
n doesn't change, but electrons' mobility ↓
at higher temp atoms vibrate more strongly → free electrons have more collision (more scattering)

intrinsic semiconductors
↳ number n = number of holes (p)

$\sigma = n|e|\mu_e + p|e|\mu_h$

extrinsic ~~P-type~~ semiconductors
doping with foreign atoms of intrinsic semiconductors
n-type: $n \gg p$ by doping with +1 element
atoms of +1 elenat act as electron donor to conduction band
p-type: $p \gg n$ by doping with -1 element
atoms of -1 element act as electron acceptor from valence band creating holes

insulators
electrical dipole



summary:

electron conduction $\sigma = \frac{1}{\rho} = n|e|\mu_e$

metals: $\rho_{tot} = \rho_{thermal} + \rho_{impurity} + \rho_{deformation}$

$\rho_{thermal} \approx aT + b$ pure metals ($b \approx 0$)

semiconductors $\sigma = n|e|\mu_e + p|e|\mu_h$

intrinsic semiconductors $n = p$

$\sigma \approx C_1 n = C_1 p = C_2 \exp\left(-\frac{E_g}{2kT}\right)$

extrinsic n-types $n \gg p$

$\sigma \approx C_a n = C_b \exp\left(-\frac{E_g - E_d}{kT}\right)$

extrinsic p-type $p \gg$

$\sigma \approx C_e p = C_d \exp\left(-\frac{E_g}{kT}\right)$

Lecture 6

6. Materials selection in mechanical design

market need → concept → embodiment → detail → production

design requirements
function: what does the component do?
objective(s): what is to be minimized / maximized?
constraints
free variables

performance $p = F$(functional requirements, geometric parameters, materials properties)

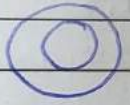
$p = F(f, g, m)$

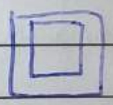
Ashby map!

shape and mode of bending

○ area matters, not shape


area & shape matter


area & shape matter


area & shape matter when buckling
in pure compression shape doesn't matter

$\phi = \frac{4\pi \ell}{A^2}$ bending $\phi = \frac{4\pi}{A^2} \int y^2 dA$

torsion $\phi = \frac{2\pi}{A^2} \int r^2 dA$


most efficient torsion

most efficiat bending if $h > b$

Part 2 Polymer science

Lecture 1

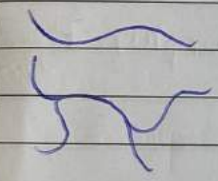
polymerization: formed by linking together monomers molecules through chemical reactions

typical properties:
- low density/lightweight
- good barrier properties
- electrical insulator
- high resistance to corrosion
- easy to process & cheap

~Ċ-Ċ~ polyethylene

polymer architecture → polymer properties

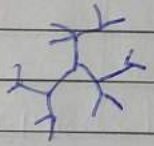
Topology



linear, branched } thermoplast:
- gets soft when heated
- not crosslinks
- mostly soluble
- can be processed by heat

comb

network → thermoset:
- crosslink during heating
- not soluble / can swell
- ✗ processable



hyperbranched

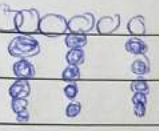
elastomer: crosslinked rubber
- polymer must be above glass transition temperature (T_g)
- polymer must have a very low degree of crystallinity
- polymer should be lightly crosslinked

composition

homopolymer → same building blocks

random copolymer → different monomers
block "
↳ properties intermediate to homopolymers
not possible by blending as most homopolymers
are immiscible with each other

graft copolymer
↳ properties characteristic of each of the homopolymers



polymers do not crystallize easily with cooling, bc requires
considerable ordering of the coiled macromolecules

some do crystallize → semi-crystalline with also amorphous regions

crystalline regions → melting temperature T_m

amorphous regions → glass transition T_g

ordered < T_m < disordered melt
crystalline
solid

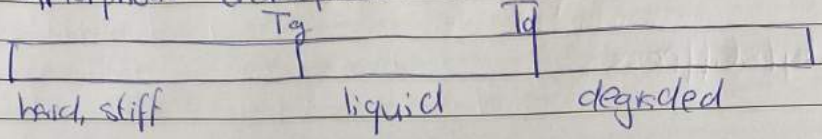
disordered amorphous solid < T_g < disordered melt
with immobile molecules

strength, stiffness & toughness → generally increases with degree
of crystallinity

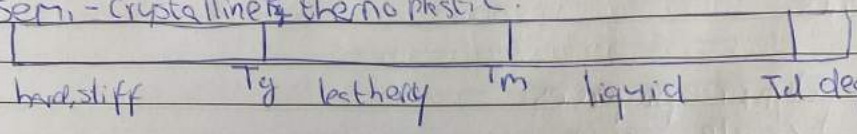
optical clarity → decreases with increasing degree of crystallinity

more barrier properties with increase of crystallinity
solvent resistance increases

Amorphous thermoplastic:

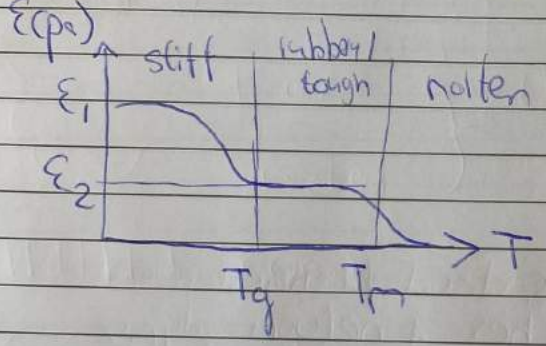


Semi-crystalline thermoplastic:



thermoset:

→ Temperature increase



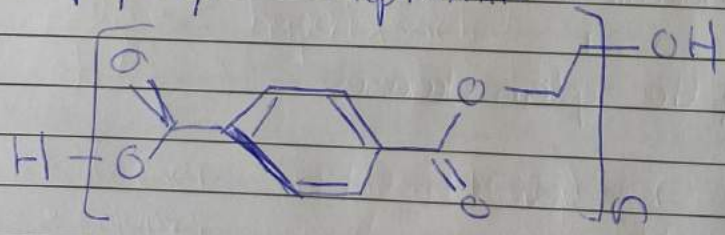
Thermoplastic

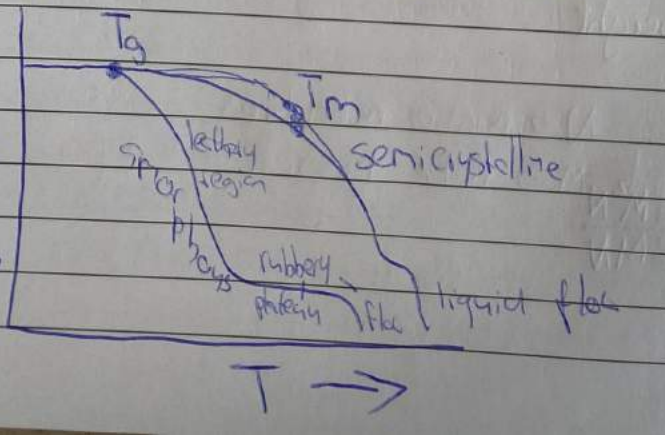
$\sigma = E \cdot \varepsilon$

↳ young modulus

Lecture 2

polyethylene terephthalate

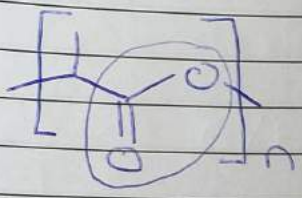




molecular weight determines physical state

polymers integrity/stiffness:
- crosslinks
- crystals
- entanglements

factors affecting polymer properties:
- chain stiffness / side groups
- plasticizers / fillers
- copolymers or blends
- test conditions
- molecular weight (distribution)



ester bond

how to polymerize a molecule
- difunctionality → double bonds, cyclic, diacids/diamines
  ↳ functionality >2 → branches & network polymer
- sufficiently reactive monomers
- pure monomers
- if monomer exists of 2 molecules (diacid & diol) the reactant ratio should be close to 1
- Gibbs free energy (G) of the system decreases
  ↳ negative

number average molecular weight

$$M_n = \frac{\sum NM}{\sum N}$$

N → number molecules
M → molar mass

weighted average $M_w = \frac{\sum M^2 N}{\sum MN}$

step-growth polymerization	chain-growth polymerization
• stepwise by reactions that can occur between say 2 molecular species	• only by reaction of monomer with a reactive end-group
• no initiator	• require an initial reaction
• slow	• fast
• ~~step~~ mostly no termination	• always termination

number average degree of polymerization $p = \frac{N_0 \rightarrow \text{initial monomers}}{N_t \rightarrow \text{number of chains}}$

$$p_n = \frac{1}{1-p}$$

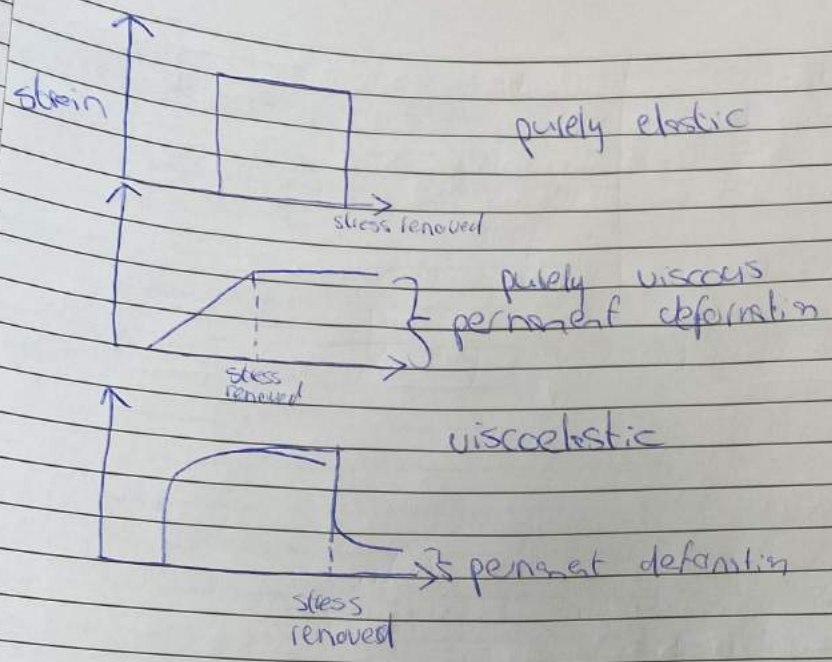
Lecture 3

Weighted average is always larger than M_n
Semi-crystalline polymers: polyethylene & polypropylene
Above T_g elastic properties
Entropy typically decreases upon polymerization
↳ energy dividing
carboxylic acid + amine → amide
Ester bonds can be broken by hydrolysis

Material is sticky if elastic modulus $< 10^5$ Pa
The softer the material, the better the contact

Pressure sensitive adhesives (PSA's)
polymer melts, made of long, flexible molecules, naturally provide the desired properties of sticky material: under stress at long timescales → viscous liquids
short timescales → deform like soft elastic solids
characteristic timescales can be tuned by chemical composition, chain length and molecular architecture & temperature

Viscoelasticity
polymers → soft matter → intermediate between solid & liquid
↳ solid on short term, liquid at long times → viscoelastic
↳ because of long entangled molecules able to make temporary connections



E (ξ) $= \sigma / \varepsilon$ → strain (%)

↓ modulus of elasticity (N/m^2)

↓ stress

Tensile test → ppolymer type, fastness experiment, temperature influence

good adhesion → spread the tack over many molecules & via entanglement / crosslinking

PSA's high M_e (average molecular weight between entanglements)

radical polymerization

initiation

$$RO\cdot + CH_2=\underset{\underset{Z}{|}}{CH} \rightarrow RO{-}CH_2\dot{C}H\underset{\underset{Z}{|}}{}$$

chain propagation

$$RO{-}CH_2\dot{C}H\underset{\underset{Z}{|}}{} + CH_2=\underset{\underset{Z}{|}}{CH} \rightarrow RO{-}CH_2\underset{\underset{Z}{|}}{C}H{-}CH_2\dot{C}H\underset{\underset{Z}{|}}{}$$

continues

termination

methods to terminate chain

- chain combi

2 $RO-[CH_2CH]_n-CH_2\dot{C}H$ (Z)

- disproportionation
- reaction with inparity

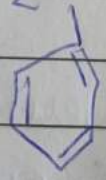
polymers

polyethylene $\sim CH_2-CH_2\sim$

poly(vinyl chloride) $\sim CH_2-CH(Cl)\sim$

polypropylene $\sim CH_2=C(CH_3)H\sim$

polystyrene $\sim CH_2-CH(C_6H_5)\sim$

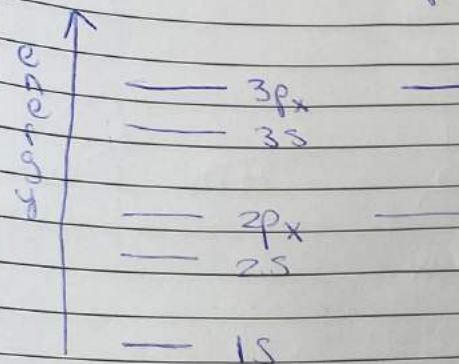


Part 3 Organic chemistry

Lecture 1

↳ carbon-based
C-C bond ideal → not too strong/weak

orbitals e⁻ clouds probability

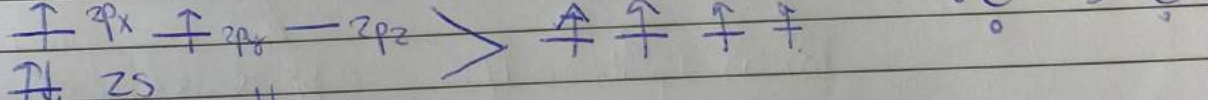


s=2 p=6

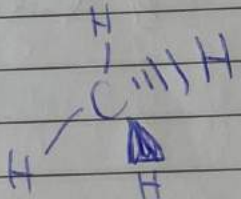
s → circle
p → ∞

Aufbau principle → fill lowest E-levels first
Pauli exclusion principle → no e⁻ can occupy the same quantum state
Hund's rule → fill all orbitals first with 1e⁻ and same spin

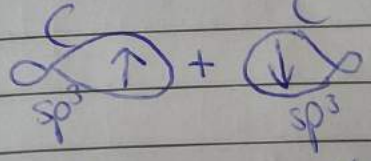
carbon sp^3 hybridization



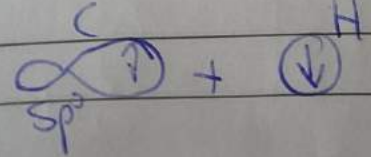
:C → ·C·



single bond

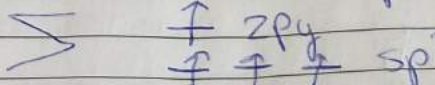


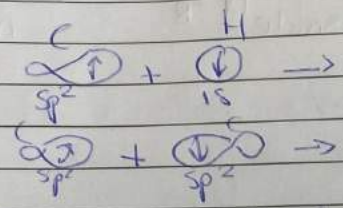
→ sigma bond $sp^3 + sp^3$



→ sigma bond $sp^3 + 1s$
σ-bond

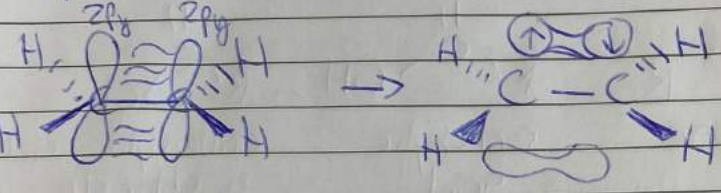
sp^2 hybridization





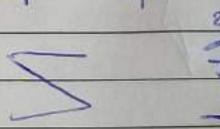
σ bond, can rotate

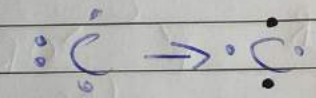
sp^2 → double bond cis/trans



π bond → rigid

sp hybridization





triple bond

aromaticity (benzene)
- cyclic
- planar
- $\pi = 4n + 2$
- odd electron pairs only $\pi/2 =$ odd

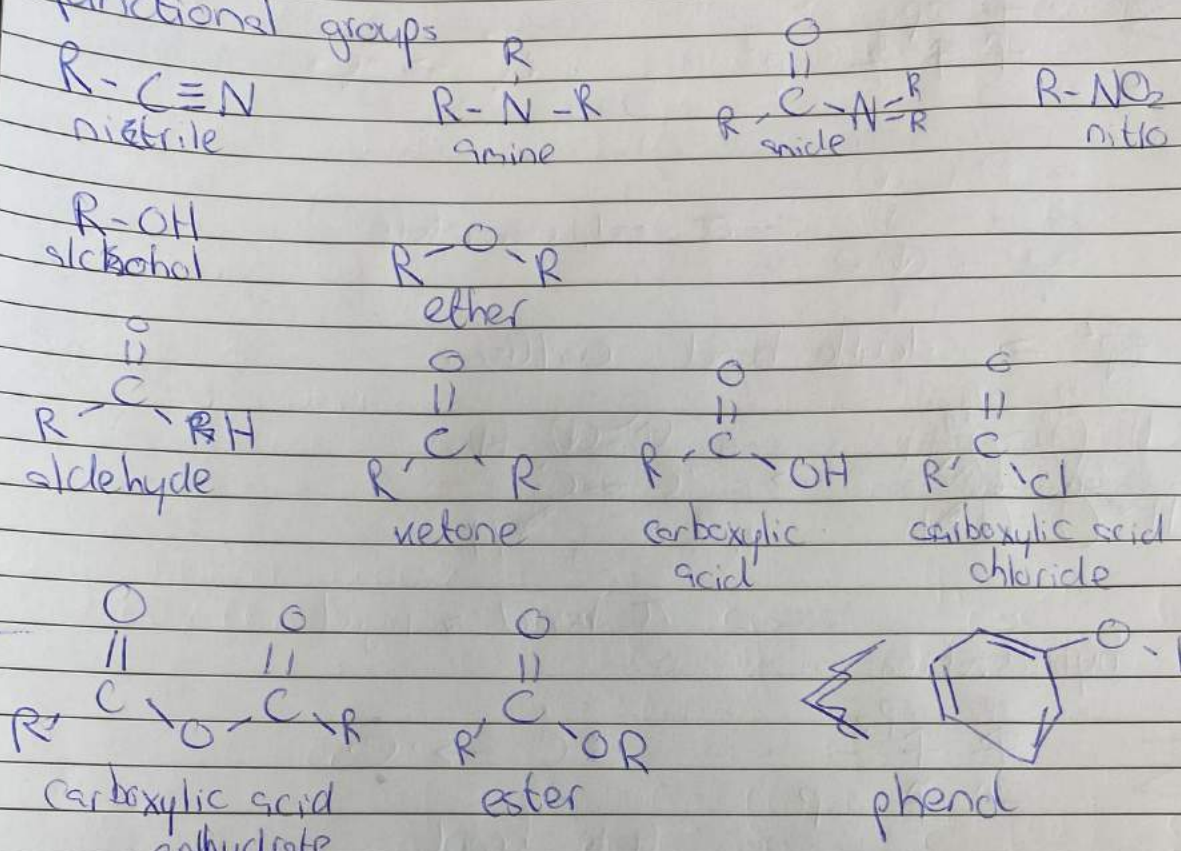
maximize distance (minimize repulsion) → 3D structure VSEPR

Lecture 2

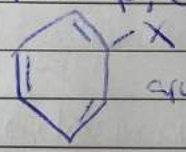
methane, ethane, propane, butane, pentane, hexane, heptane, octane, nonane, decane

saturated: single bonds
unsaturated: double/triple/aromatic bonds

functional groups



X → F, Cl, Br, I (halides)



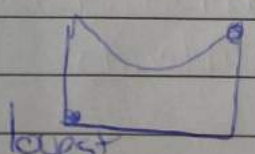
aryl halide

R-X
alkyl halide

primary → 1 R
secondary → 2 R
tertiary → 3 R
quaternary → 4 R

H's don't count

Intermolecular interactions
- polarity (molecule)
- electronegativity (bonds)



$\varepsilon_{11} = \frac{\sigma}{E}$ $\quad \varepsilon_{\perp} = -\nu \frac{\sigma}{E}$

$E \rightarrow$ young modulus, measure of stiffness
$\nu \rightarrow$ poisson ratio

if stress disappears the non-elastic part of the strain remains
- atomic planes start to slide along each other
- sliding of planes is possible by movement of dislocations

elastic limit: highest stress possible without plastic deformation
yield strength: at which yielding (large) occurs

tensile strength: maximum strength material can withstand
↳ decreasing load is needed for an increasing strain
sudden increase in strain is because of rapid thinning & elongation → necking

~~ρ~~ $\rho_A = N/m^2$ to kg/m^2 with $g = g_0 \delta_1$ (divided by)

ductility: deformability (plastic)
ductile → lot residual permanent strain
brittle → little " " "

surface below stress-strain curve → energy per unit volume to deform/fracture material
$U = \int F ds$ → large surface ⇒ toughness

$\sigma_{applied} = \frac{\sigma_{yield}}{N}$ $\quad N \rightarrow$ safety factor

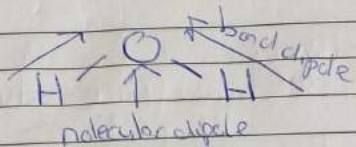
Lecture 3

elastic to plastic transition → crystal planes start mutual sliding

3. Dislocations and strengthening mechanisms

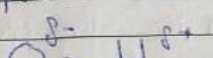
dislocations → line defect
- edge: extra half crystal plane Burgers vector ⊥ dislocation line
- screw: dislocation of one crystal plane with every 360° turn Burgers vector // dislocation line

dipole moment



dipole - dipole interaction

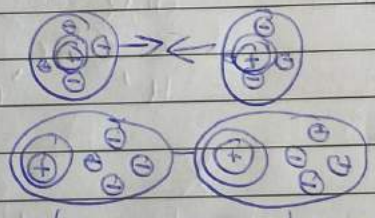
hydrogen bonding (N-H / O-H) also dipole
→ non-covalent, highly polarized
→ strong (H small)
→ donor & acceptor



ionic interactions → exchange of electron
→ high boiling point / usually solid

pi-pi interactions
↳ between 2 unsaturated hydrocarbons
↳ strongest for aromatic systems
↳ electrons easily distorted induced dipoles
π-π stacking → benzene rings

Van der Waals interactions
→ weakest
→ non-polar molecules (alkanes)
→ always present



atoms are polarized & attract

strength: covalent → ionic → H-bonding → π-π → vdW

better stackable molecules → higher melting point
→ unbranched

more sphere like → better stacking → higher melting point
→ lower surface area → lower boiling point

hydrophobic effect (solubility)
polar molecules dissolve in H_2O bc hydrogen bonds with H_2O
nonpolar " group together in H_2O, → form hydrogen " with eachother

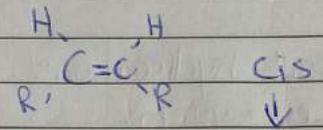
Solubility occurs if interaction is favorable enough to compensate for loss in intermolecular interactions of the solvent & solute

factors that influence boiling/melting point
- molecular weight
- polarizability
- intermolecular interactions

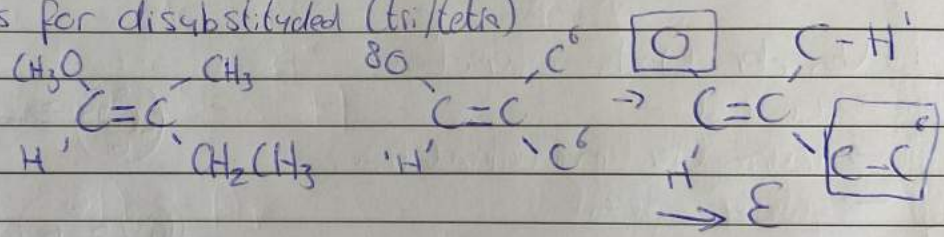
Lecture 3

structural isomers → same molecular formula, different structural

regioisomers → specific structural isomers that can be obtained from a give reaction → undesired byproduct

Configurational isomers → 

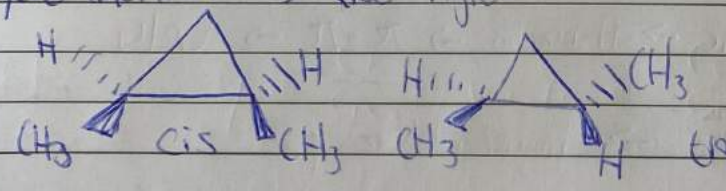
- cis/trans
  - cis → amorphous
  - trans → semi-crystalline
- E/Z → cis/trans for disubstituted (tri/tetra)
  - → together
  - → opposite



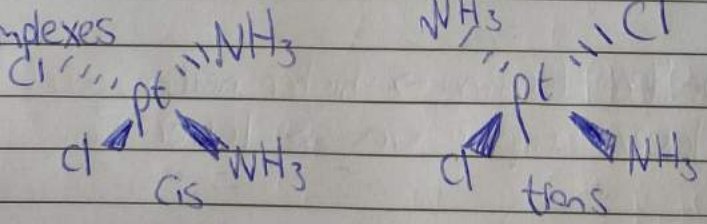
atomic number
molecular weight


→ E

- cycloalkenes → also rigid



- metal complexes



- optical isomers

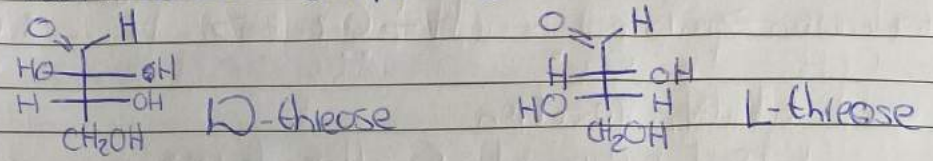
chirality → chiral: different mirror image, no symmetry plane
achiral: the same

asymmetric C (chiral centre) 4 different substituents

optical isomers:

- Fischer projections D/L forms
  (right / left)

short bottom chiral C

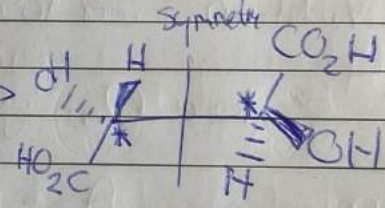


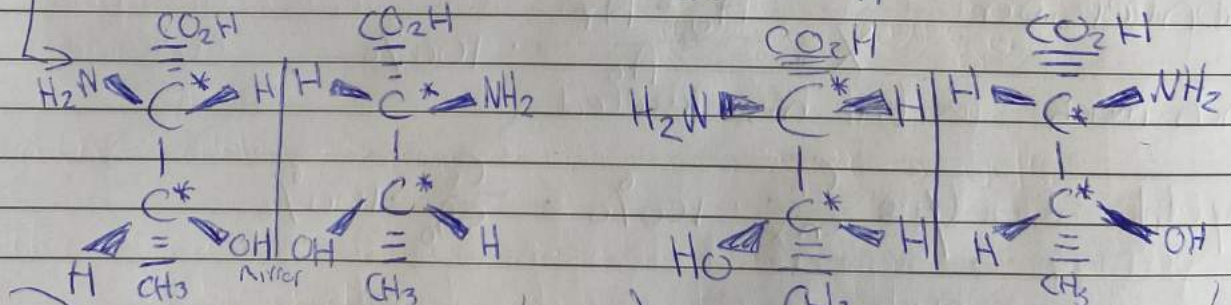
optical isomers → exact same properties
but rotation of polarized light
mixtures of exact opposite no rotation

- R and S
  right left
  clockwise counterclockwise
  highest priority to lowest (circle)
  double bonds count twice for priority

1. atomic number
2. point lowest away
3. rotate

- meso and diastereomers
  meso → identical
  diastereomers → not mirror images





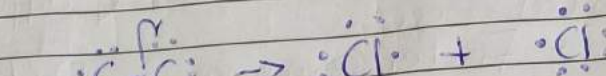
enantiomers: non-superimposable mirror images

diastereomers → ~~non-superimposable~~ mirror images

different properties!

optical isomers only differ in interaction with other sources of chirality
→ chiral compounds / light

chemical reactions

homolytic cleavage 

heterolytic cleavage electron pairs 

- substitution reaction
  1 bond breaks at C other forms
- addition
  unsaturated compounds → break π bond form 2 new single C bonds
- elimination
  reverse of addition form C-C π bond
- redox → gain O, lose H
  oxidation: ~~Fe~~ lose e^- → combustion
  reduction: gain e^-
  ↳ lose O, gain H

conversion $X = \frac{A_0 - A_T}{A_0} \cdot 100\%$

how much reactant has reacted

yield $Y = \frac{C_t}{C_{ex}} \cdot 100\% = \frac{C_t}{A_0} \cdot 100\%$

how much desired product formed

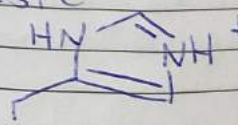
$A + B \rightarrow C + D$

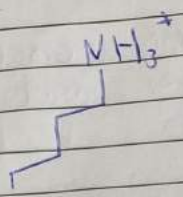
selectivity $S = \frac{B_t}{C_t}$ or $S = \frac{B_t}{B_t + C_t} \cdot 100\%$ $A \rightarrow B$ $A \rightarrow C$

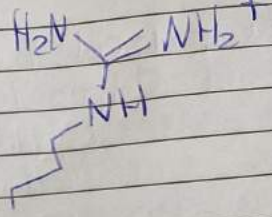
atom economy $AE = \frac{m_C}{m_A + m_B} \cdot 100\%$

environmental factor $E = \frac{m_Q}{m_C}$

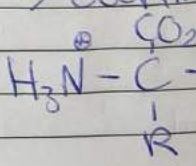
7. basic







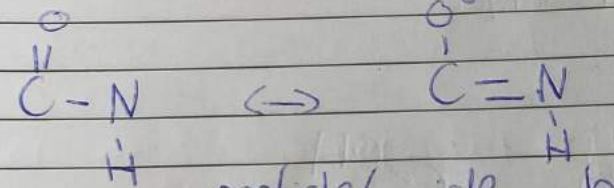
zwitter ions → overall neutral molecules but contain charged ends



isoelectric point: pH at which there is no net charge
↳ pI of ionizable amino acid is avg of pKa values of the similar ionizing groups

peptides → amino acid polymers (2-50 units)
proteins → peptides >50 units

amide nitrogen sp^2



peptide/amide bond

only other covalent bond between amino acids: disulfide linkage
cysteine

-S-S-

protein structures

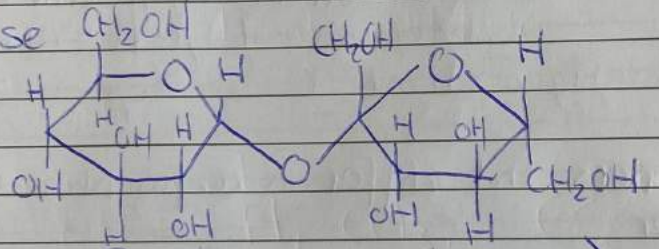
primary → sequence of chain amino acids
secondary → when sequence are linked with hydrogen bonds
α-helix / β-sheet
tertiary → occurs when certain attractions present between
quaternary → protein of more than 1 amino acid chain

forces stabilizing protein structure
- covalent (primary)
  single bonds C-H C-C C-N C-O
- covalent (secondary / tertiary)
  disulfide S-S
- non-covalent
  - H-bonds
  - hydrophobic
  - ionic
  - van der Waals

most oxidized C disu st top

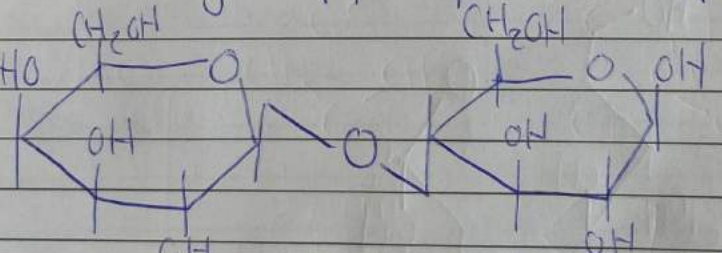
Lecture 2
The lower the pKa, the stronger the acid → more stability to donate its protons

sucrose



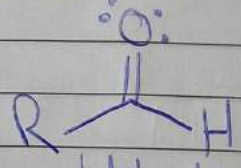
α-D-glucopyranosyl-(1→2)-β-D fructofuranoside

lactose



β-D-galactopyranosyl (1→4)-D-glucose

Carbohydrates → saccharides
↳ -ose ↳ $C_n(H_2O)_n$



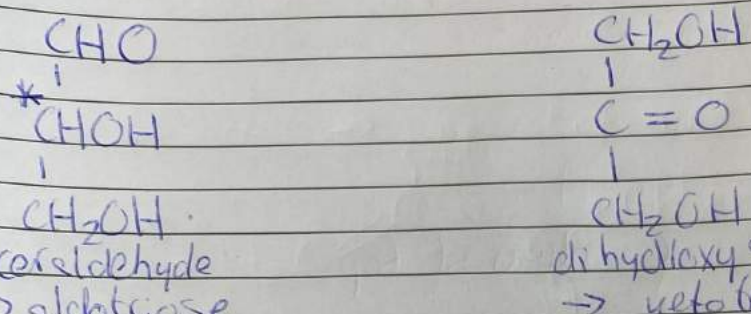
aldehyde

ketone

D in nature

monosaccharides

- colorless, crystalline, solids
- hydrogen bonds between poly-OH & H_2O
- soluble in H_2O, slightly in alcohol
- insoluble in non-hydroxylic solvents



glyceraldehyde → aldotriose

dihydroxyacetone → ketotriose

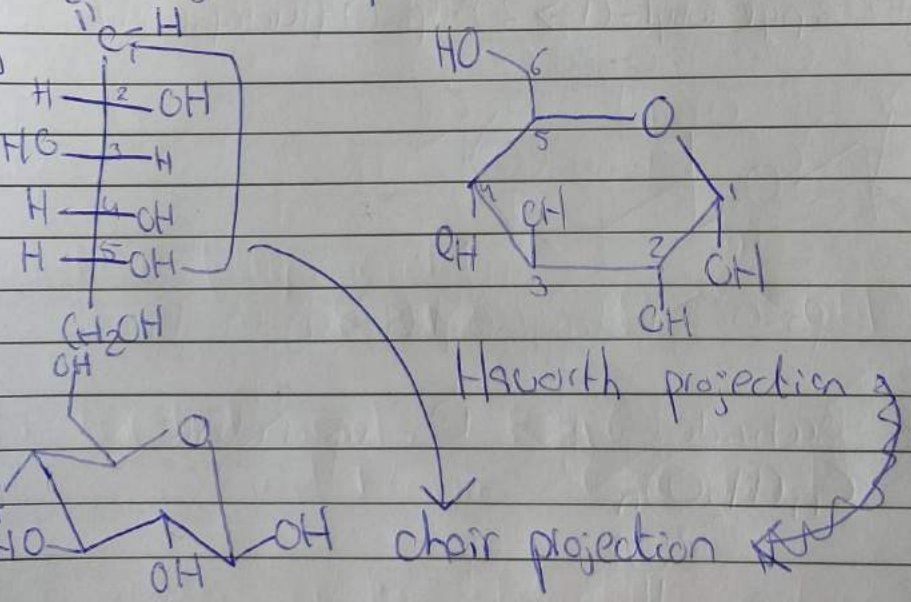
Fischer projections

OH group attached to most bottom asymmetric center determines D/L

vertically drawn, most highly oxidized C at top

epimers → diastereomers that differ in configuration at 1 C*

e.g. C2-epimer



Haworth projection

chair projection

OH left → up

OH right → down

down: α

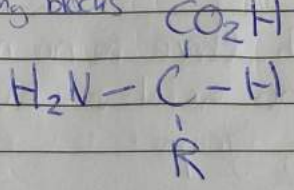
up: β → anomers

catalyst, used but not consumed
- use of diffent/greener reactants
- less steps / faster
- less side products
- less energy

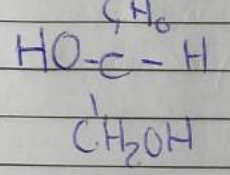
Part 4: Bio~~molecules~~ chemistry

lecture 1

amino acids α-amino carboxylic acids
↳ protein building blocks



except for glycine (R=H) α → chiral

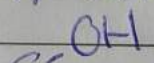


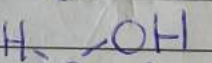
L-glyceraldehyde

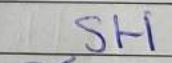
20 amino acids

1. small R= H, CH_3,

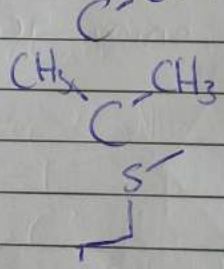
2. nucleophobic

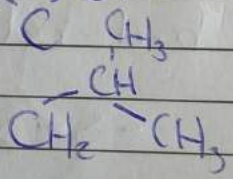


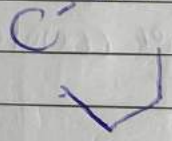


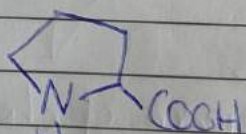


3. hydrophobic

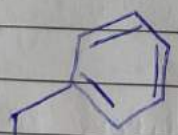


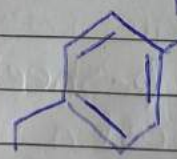


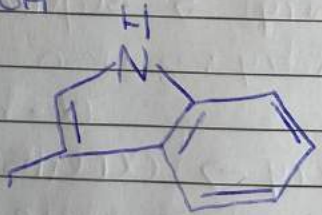




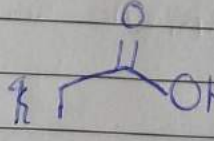
4. aromatic

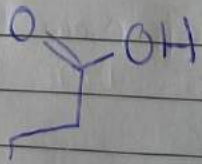




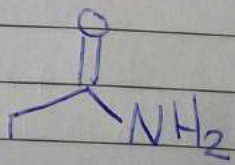


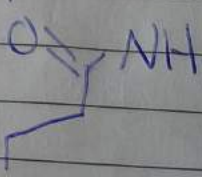
5. acidic





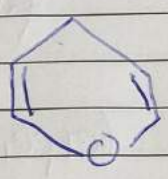
6. amide



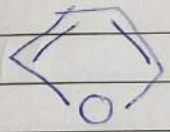


convert from α to β → open-chain aldehyde form in aqueous solution
↳ mutarotation
α anomer → -OH is trans (axial) to terminal $-CH_2OH$
β " → -OH is cis (equatorial) to " "

Cyclic structures of monosaccharides
6 membered hemiacetal rings
→ pyranoses (heterocycle: pyran)



5 membered hemiacetal rings
→ furanoses (heterocycle: furan)



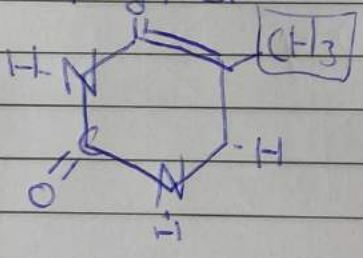
Lecture 3

DNA double helix, ~~B~~ OH, ~~B~~, O-H hydrogen bonds keep strings together

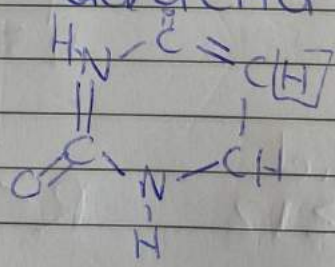
A - T T - A → 1 OH + 1 NH
C - G G - C → 2 OH + 1 NH

DNA & RNA → nucleic acids
↳ double stranded → single stranded
deoxyribose as sugar ribose

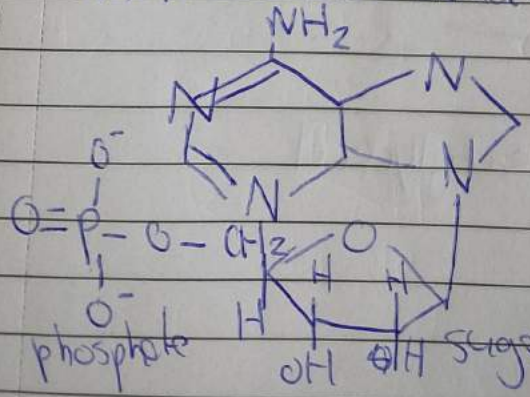
TCAG



~~U~~UCAG



nucleotides structure



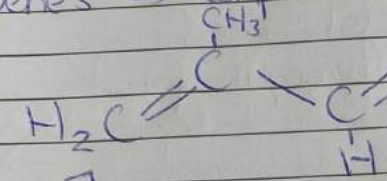
lipids: hydrophobic biorgasic compounds not soluble in H_2O

- wax → ester of long chain carboxylic acids + long chain alcohols

$CH_3(CH_2)_{14}-C(=O)-O-(CH_2)_{25-31}CH_3$

fatlike substace with melting point ≥ 45°C
no melting profile

- terpenes → composed of 1/more isoprene units



monoterpenes → 2 isoprenes

#C	#isoprene	#terpenes	name
5	1	½	heni terpene
10	2	1	mono
15	3	1.5	sesqui
20	4	2	di
25	5	2.5	sester
30	6	3	tri
35	7	3.5	sesqui
40	8	4	tetra
>45	9	4.5	poly

saturated fatty acid
$R \geq 12$ $R-C(=O)-OH$

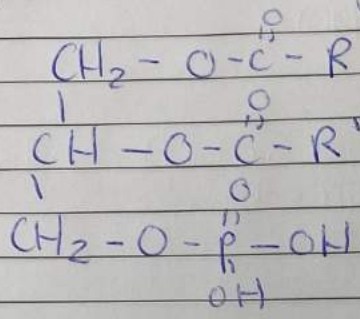
unsaturated acids $R \geq 16$
and 1/more $C=C$ bonds

fats → esters of long chain fatty acids + glycerol

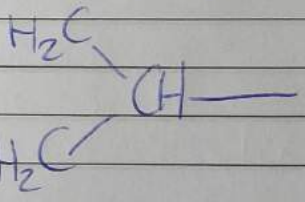
CH_2-OH
$CH-OH$
CH_2-OH
glycerol/glyceride

$CH_2-O-C(=O)-R$
$CH-O-C(=O)-R'$
$CH_2-O-C(=O)-R''$
triglyceride

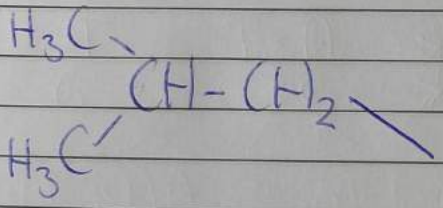
phosfoglycerides: lipids of 2 fatty acids and a phosphoric acid attached to glycerol



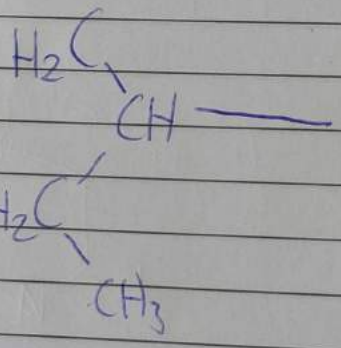
Alkyl groups naming



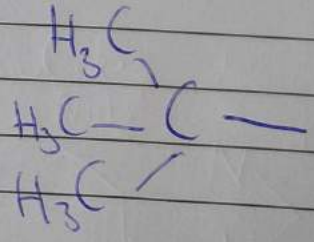
isopropyl
(1-methylethyl)



isobutyl
(2-methylpropyl)



sec-butyl
(2-butyl



tert-butyl