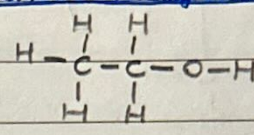
<ORGANIC CHEM>

alkyl →
ester →
amide →

HOMOLOGOUS SERIES

a family of molecules that
- a general formula
- similar chemical properties (due to same functional group) ↗ atom/grp of atoms responsible for the chemical and physical properties of the compounds
- gradual change of physical properties — m.p, b.p, viscosity, flammability (due to ↑ in size and mass of molecules)

both show functional series

MOLECULAR FORMULA	STRUCTURAL FORMULA
shows type of elements and total atoms, ✗ arrangement of atoms	(all bonds displayed) shows how atoms are covalently bonded to one another in the molecule
Ethanol → C_2H_5OH – 3 elements (C, H, O) – total of 9 atoms	Ethanol: 

NAMING
- PREFIX : no. of C atoms — meth- 1, eth- 2, prop- 3, but- 4, pent- 5, hex- 6
- SUFFIX : homologous series — -ane alkane, -ene alkene, -an-ol alcohol, -an-oic acid carboxylic acid / organic acid

ALKANES (g) (rtp)

- obtained directly from fractional distillation of petroleum / crude oil
- general formula: C_nH_{2n+2} (– differ by CH_2)
- saturated hydrocarbons (compounds that contain only elements carbon and hydrogen)
  - ↳ molecule contains only carbon–carbon single bonds (C–C)
  - ↳ each C atom is covalently bonded to 4 other atoms (maximum no. of atoms), so no new atom can add to it anymore ∴ generally unreactive # (large amt of energy to start chem rxn)
- not soluble in water, soluble in most organic solvents, may be used as solvents – unreactive

		condensed formula
Methane	– CH_4	CH_4
Ethane	– C_2H_6	CH_3CH_3
Propane	– C_3H_8	$CH_3CH_2CH_3$
Butane	– C_4H_{10}	$CH_3CH_2CH_2CH_3$

size and mass of molecules ↑ down the series
- → melting, boiling point ↑ – ↑ intermolecular force (↑ Mr) ← bigger molecule
- → density ↑ – mass ↑ more than volume? eg. ↑ than…
- → viscosity ↑ – larger molecule ↗ ↑ intermolecular force → harder for molecules to slide past one another #
- → flammability ↓ – larger molecule → more covalent bonds btwn atoms ↗ ↑ energy needed to start rxn #

Chemical RXNS:

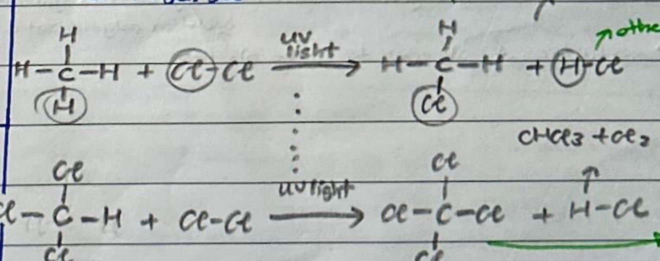
① COMBUSTION

- exothermic
- complete combustion: (same as alcohols)
  - ↳ burn w blue flame w/o smoke / clean flame
  - ↳ alkane + O_2(g) → CO_2(g) + H_2O(l) (balance C, H, O)
- incomplete combustion: (combust in limited O_2 ↓ may produce soot, CO)
  - ↳ burn w yellow smoky flame
  - ↳ possible products: CO*, soot C(s)*, H_2O
  - alkane + O_2 → CO + H_2O or CO + H_2O + C(s)

② SUBSTITUTION

- catalyst : presence of UV light
- *each H atom in alkane is displaced one at a time by one molecule of halogen gas
- All H in alkane can be replaced in excess halogen gas

$CH_4 + Cl_2 \rightarrow CH_3Cl + HCl$



chloromethane (alkane used; from halogen: bromine → bromo, fluorine → fluoro)

$CHCl_3 + Cl_2 \rightarrow CCl_4 + HCl$

tetrachloromethane ("four"; di → two, tri → three)

overall eq: $CH_4 + 4Cl_2 \rightarrow CCl_4 + 4HCl$

③ CRACKING – see behind

(diff? or added?)

- bending is not an isomer
- reflection is not an isomer
- rotation is not an isomer

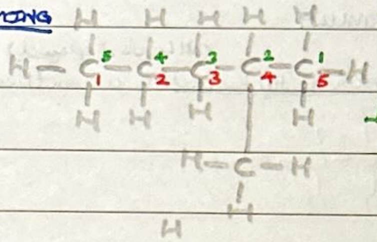
ISOMERS of alkanes.

↳ compounds that have same molecular formulae but different structural formulae
(same molecular formulae: diff → diff homologous series; same → same homologous series)
(different structural formulae → diff physical properties (mp. bp.))

→ Straight-chain — C atoms connecting in a single continuous line

→ branched-chain — C atoms not in a 〃 and form a side-chain → alkyl group $(-C_nH_{2n+1})$ ⇒ methyl → $-CH_3$, ethyl → $-C_2H_5$, propyl → $-C_3H_7$

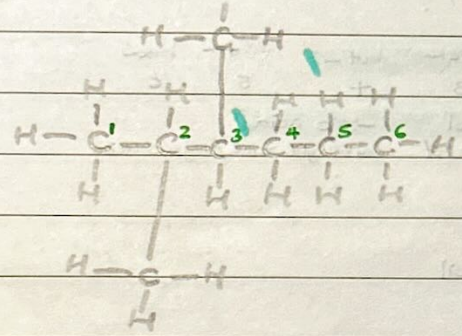
NAMING



this is da 'main chain'

2 — methyl pentane

- 2 → lowest position of C atom (follow green) → 2; red → 4
- methyl → alkyl group
- pentane → name of main chain



2, 3 — dimethyl hexane

③ **CRACKING reaction** of alkanes — Breaking down of large alkane molecules to produce smaller useful molecules.

Smaller alkanes — % by mass of C is low — can burn easily → more efficient as fuel ↙ can cater to demands for fuel (smaller = more useful)

Catalytic cracking → Aluminium oxide (Al_2O_3) or (SiO_2) Silicon dioxide as a catalyst

High temp → 500°C to 700°C (600°C) ☆

Low pressure → 1 atm — no need write?

or just 'cracking' → high temp & pr w/o catalyst

Possible Reaction #1 : large alkane $\xrightarrow{\wedge}$ mixture of alkenes + alkane (ONE)^{mole}

$C_{10}H_{22} \rightarrow C_5H_{12} + C_5H_{10}$ ☆ ?

Possible Reaction #2: large alkane $\xrightarrow{\wedge}$ mixture of alkenes + $H_2(g)$ (ONE)^{mole}

$C_{10}H_{22} \rightarrow H_2 + C_{10}H_{20}$

alkenes → can be collected via displacement of water

- applied in → production of hydrogen for manufacturing of margarine (hydrogenation) or ammonia (Haber Process)
- → production of alkenes to make plastics (addition polymerisation)

molecule → (micro lvl)
compound → (macro lvl)

☆ Ethene – C_2H_4
Propene – C_3H_6
Butene – C_4H_8
} m.p., b.p. ↑, density ↑, viscosity ↑, flammability ↓

ALKENES – (g) r.t.p.

(hydrogenation)
C=C break → which form single bond C–C ↳ saturated compound #
↑ New atoms can be added to the C atoms that form the double bond. ☆

· obtained mainly from cracking of alkanes

· general formula: C_nH_{2n} (1 : 2) (– differs by CH_2)

· unsaturated hydrocarbons (see alkanes) – molecule contains carbon–carbon double bonds (C=C) ↗ generally reactive #
↳ each C atom that forms double bond is covalently bonded to three atoms, so a new atom can be added to it

· insoluble in water, soluble in most organic solvents, not used as solvents — may interfere with reactions (more reactive).
usually used as starting materials for making products like plastic, detergents

Chemical RXNS:

① COMBUSTION
· exothermic
· complete combustion:
CHO alkene + O_2(g) → CO_2(g) + H_2O(l)
✱ alkenes burn w a sootier flame than alkanes
↳ (percentage of carbon by mass) in alkene is ↑ than alkanes, for the same number of C atoms present in their respective molecules.
$\frac{Ar \text{ of } C\ (12) \times \text{No. of C atoms}}{\text{total } Mr} \times 100\%$
↳ ↑ C atoms incompletely combusted ↳ product = C(s)

③ ADDITION POLYMERISATION
(see polymers)
· process of joining small identical units to form large molecules.
· alkenes are unsaturated, ∴ can be used to produce large molecules thru ^^ (see later)

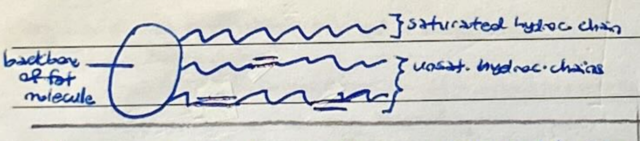
② ADDITION
– chem. rxn that allows atoms to be added to molecule

Ⓐ → HYDRATION — addition of steam
alkene (g) + steam (g) → alcohol
catalyst: concentrated phosphoric(V) acid [H_3PO_4], 300°C, 60 atm

Ⓑ → HYDROGENATION – addition of hydrogen
alkene (g) + hydrogen (g) → alkane (g)
catalyst (transition metal): nickel, high temp (150°C?), high pr ☆
(high mp bp, variable oxidation st. why? ch 14)

– Hydrogenation and unsaturated compounds (fats...)

When two or more C=C bonds in the same hydrocarbon chain → polyunsaturated chain



✱ The greater the level of saturation (more C–C, less C=C) in the chains, the higher the melting point of the fat.

∴ Fats ⇒ solid at r.t.p. (↑ m.p.) → contain mainly saturated hydrocarbons
↳ saturated hydrocarbon chains stack well w one another ↳ can come close tgt
↳ ∴ intermolecular fca btwn the chains stronger ↳ more energy needed to overcome them #

∴ Oils ⇒ liquid at r.t.p. (↓ m.p.) → contain unsaturated hydrocarbons
↳ C=C bonds in unsaturated hydrocarbon chain causes structure of chain to bend
↳ do not stack well, cannot come close tgt
↳ ∴ intermolecular fca weaker
↳ less energy needed to overcome them #

– Hydrogenation and converting unsaturated hydroc. into saturated hydroc. (Margarine making)

Vegetable oils → polyunsaturated – generally exist as (l) at r.t.p.
add hydrogen | nickel, 150°C ↓
how? → hydrogenation of oil ↓ C=C in veg. oil molecules
form solid margarine ↳ margarine exists as a solid at r.t.p. (hardens)

(+ve): → more convenient to use (more spreadable)
→ not spoil quickly

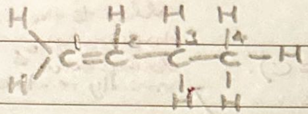
(–ve): → process can give rise to partial hydrogenation of veg. oil
↳ margarine still contains some unsat. hydroc. → negate +ve effect(?)
→ side reaction → lead to formation of trans fats → associated w CVD diseases ∴ unsaturated fats – healthier

Ⓒ → BROMINATION – addition of bromine (Halogenation)
distinguish alkene vs alkane → alkene/unsaturated hydroc. → decolourised (brown bromine → colourless)
→ alkane/saturated hydroc. → no rxn, bromine remains brown.
– indicate amt of unsat. fats → more unsat., ↑ amt of bromine decolourised/reacted ↳ can decolourise more drops of Br (l).

ethene (g) + bromine (aq) → 1,2 – dibromoethane (aq)
C_2H_4 + Br → $C_2H_4Br_2$
↳ colourless ↳ brown ↳ colourless

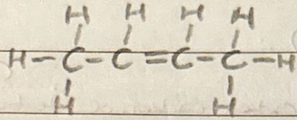
ISOMERS OF ALKENES - for alkenes w 4 or more C atoms

→ position of C=C bond (functional grp) in a straight chain



(1)-butene

take the lowest no. possible (L→R or R→L)

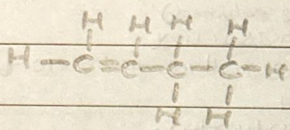


2-butene

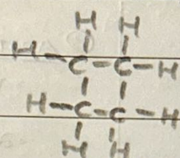
⇒ ∴ C(1)=-C-C-C and C-C-C=C(1) are not isomers

→ position of alkyl group (branched-chain)

→ different homologous series (but same molecular formula, w diff structural formula)



butene - alkene



cyclobutane - not alkene.

↗ diff? ☆

ALCOHOL (l) (aq)

- general formula: $C_nH_{2n+1}OH$
- contains a functional group — hydroxyl (—O—H)

Methanol	CH_3OH	→ Solubility in water ↓ — as size and mass ↑
Ethanol	C_2H_5OH	→ M.p, B.p ↑ — size and mass ↑ ↳ intermolecular fo.a ↑ when Mr ↑ ↳ need more energy to overcome
Propanol	C_3H_7OH	
Butanol	C_4H_9OH	

ETHANOL

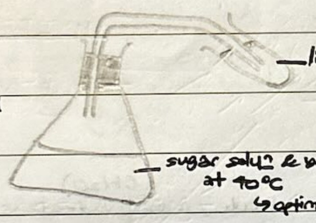
Uses:
→ raw material to make ethanoic acid
→ manufacture alcoholic beverages
→ fuel for vehicles
→ industrial solvents for making paints or perfumes

→ Way to produce ethanol #1 : FERMENTATION OF GLUCOSE (only ethanol)

glucose —yeast, 40°C?→ ethanol + carbon dioxide

$C_6H_{12}O_6$ (aq) —yeast→ $2C_2H_5OH$ (aq) + $2CO_2$ (g)

Conditions:
- catalyst: yeast — enzyme less active, ROR ↓
- temp (38–40°C) — not too high / too low
  ↳ may denature enzyme in yeast if too ↑
  ↳ fermentation X.
- absence of oxygen → ethanol oxidised to ethanoic acid when O_2 present :P (see Carboxylic acid)
  achieved thru ↓
  - stopper to prevent air from entering flask
  - limewater soln — test for CO_2 (g) — if ferm. is happening; prevent air from entering flask



separate ethanol from solution
↳ fractional distillation

(-ve)
→ produces a relatively low concentration of ethanol (8–10%)
↳ when conc. of ethanol too high → kill yeast → stop fermentation

(+ve) → glucose more widely sourced (Brazil-sugarcane...)
→ more sustainable
↳ glucose comes from plants — renewable source

→ Way to produce ethanol (or any alcohol) #2: CATALYTIC ADDITION OF STEAM TO ETHENE (alkene) (↗ see hydration)

↗ doesn't exist (need 2C ∂ C=C)
* does not work for methene → methanol

ethene + steam —H_3PO_4, 300°C, 60atm→ ethanol

C_2H_4(g) + H_2O(g) —M→ C_2H_5OH (aq)

(-ve) → not sustainable
↳ ethene derived from refining and cracking of crude oil — non-renewable resource

ISOMERS of alcohols

(↑ lowest C position; ↗ ∝ be same no. C position; → same molecule ∴ not isomer)

→ position of —OH group in a straight-chain
→ presence of alkyl group in the longest straight chain → branched-chain

chemical rxns:

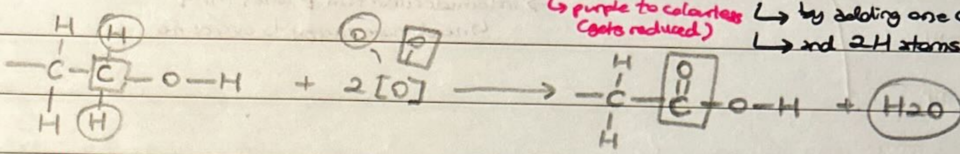
① **COMBUSTION**

→ burn w blue flame w/o soot / clean flame (↗ same as alkanes)

complete combustion: alcohol + O_2 (g) → CO_2 (g) + H_2O (l)   CHO

② **OXIDATION** by heating with an oxidising agent / atmospheric O_2 (?)

- heat w an oxidising agent (eg. acidified $KMnO_4$) → alcohol can be oxidised into a carboxylic acid
  - ↳ purple to colourless (gets reduced)
  - ↳ by adding one O atom to C atom bonded to O–H
  - ↳ and 2H atoms removed to form water w 1 O atom



ethanol + oxygen from oxidising agent —heat→ ethanoic acid + water

CH_3CH_2OH (aq) + 2[O] —heat→ CH_3COOH (aq) + H_2O (l)

C_2H_5OH (aq)

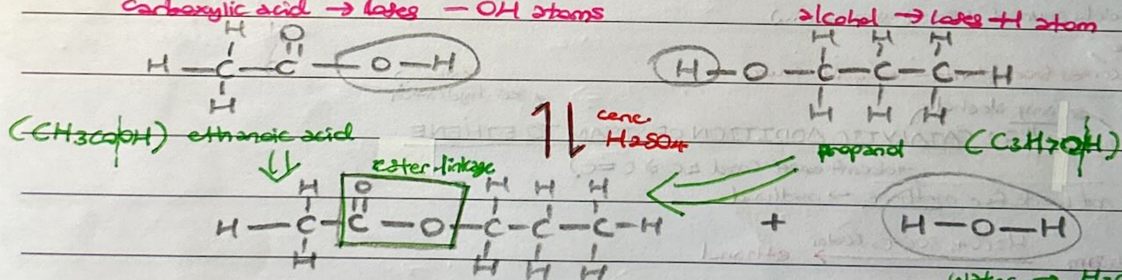
③ **ESTERIFICATION**

carboxylic acid + alcohol → ester + water (see later)

ESTERS — Reversible rxn!!!

- molecules w sweet-smelling properties — perfumes / artificial food flavouring
- produced from rxn between carboxylic acid & alcohol, water produced too
  - ↳ esterification / condensation → two molecules combine to form a single molecule, a small molecule is removed (H_2O)
- catalyst: concentrated sulfuric acid (conc H_3PO_4 → hydration (alkene))
- ester linkage: —COO— , —C(=O)—O—

carboxylic acid → loses —OH atoms   alcohol → loses H atom



propyl ethanoate → $CH_3COOC_3H_7$ (acid)

alcohol: —anol → —yl   —noic acid → —noate (see carboxylate salt in carb. acids)

Reverse (find reactants)

① split C(=O)–O

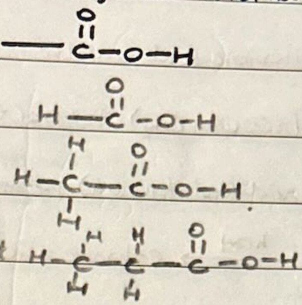
② Add —OH to C=O (carboxylic acid)

Add —H to O (alcohol)

* Fats → triesters (3 ester linkages)

CARBOXYLIC ACIDS $[(n-1)\times 2]+1$

- general formula: $C_{n-1}H_{2n-1}COOH$, n = total no. of C atoms (prefix)
- functional group: carboxyl,



Methanoic Acid $HCOOH$

Ethanoic Acid CH_3COOH

Propanoic Acid C_2H_5COOH

Butanoic Acid C_3H_7COOH

- m.p. / b.p. ↑ — Mr ↑ → intermolecular forces ↑ (molecular size ↑)
  - carboxylic acids have ↑ mp, bp. than alcohols & hydrocarbons w same no. of C atoms
- weak acids — ionise partially in water to produce H^+ ions
  - $CH_3COOH(aq) \rightleftharpoons CH_3COO^-(aq) + H^+(aq)$
- ∴ sim. prop. as acids
  - → sour taste
  - → turns blue litmus paper red
  - → reacts w metals, carbonates, bases/alkalis to form salts

Chem. RXNS:

RXN w METALS

—anoic acid → —anoate (charge of −1)

acid + metal → salt (carboxylate, metal) + hydrogen gas

ethanoic acid + potassium → potassium ethanoate + hydrogen

$2CH_3COOH(aq) + 2K(s) \longrightarrow 2CH_3COOK(aq) + H_2(g)$

2KCH3COO — why metal behind?

RXN w CARBONATES

acid + carbonate → carboxylate salt + carbon dioxide + water

propanoic acid + magnesium carbonate → magnesium propanoate + carbon dioxide + water

$2C_2H_5COOH(aq) + MgCO_3(s) \longrightarrow (C_2H_5COO)_2Mg(aq) + CO_2(g) + H_2O(l)$

RXN w ALKALIS/BASES

Grp 1 / Ammonia → (aq)

acid + base/alkali → carboxylate salt + water

methanoic acid + calcium oxide → calcium methanoate + water

$HCOOH(aq) + CaO(s) \longrightarrow (HCOO)_2Ca(aq) + H_2O(l)$

ESTERIFICATION (See alcohols)

carboxylic acid + alcohol → ester + water oxidation

(repeat of alcohols)

fermentation ++ gone wrong

(from fermentation - alcohols)

colourless liquid, found in vinegar

FORMATION OF ETHANOIC ACID

— oxidise ethanol to produce ethanoic acid

#1 → By bacteria in the air in the presence of O_2 → ∴ alcoholic drinks left in open air → turn sour due to oxidation of ethanol by bacteria to ethanoic acid

(sour — characteristic of acid)

ethanol + oxygen $\xrightarrow{\text{bacteria}}$ ethanoic acid + water

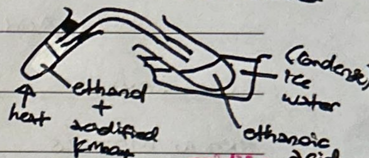
$C_2H_5OH_{(aq)} + O_{2(g)} \xrightarrow{\sim} CH_3COOH_{(aq)} + H_2O_{(l)}$

#2 → By heating with oxidising agents (such as acidified $KMnO_4$) potassium maganate (VII)

↓ show if oxidation of ethanol occured

ethanol + oxygen from oxidising agent $\xrightarrow{\text{heat}}$ ethanoic acid + water

$C_2H_5OH_{(aq)} + 2[O] \xrightarrow{\sim} CH_3COOH_{(aq)} + H_2O_{(l)}$



→ $KMnO_4$ — purple → colourless (oxidises ethanol, itself is reduced)

→ blue litmus paper dipped into ethanoic acid → red

Macromolecules → large molecules containing large numbers of atoms joined together by covalent bonds. (hundreds or thousands)

POLYMERS → a macromolecule composed of smaller repeating units connected by covalent bonds.

- large substances formed from many small molecules (monomers) → small repeating unit in a polymer bonded together

POLYMERISATION

↳ process of joining many monomers to form a polymer

diff monomers = diff polymers

- two types — Addition polymerisation / — Condensation polymerisation

#1: ADDITION POLYMERISATION (alkenes)

- monomers used are unsaturated (contain C=C bonds)

$$n(CH_2 = CH_2) \xrightarrow[\text{catalyst}]{\text{high temp \& pr}} -\!\!\left(CH_2 - CH_2\right)_n\!\!-$$

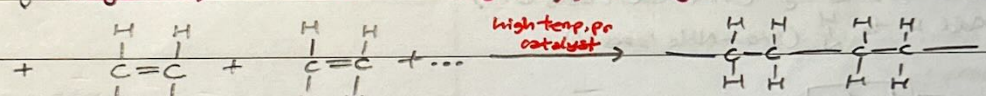
n = large no. of alkene molecules

→ Carbon-carbon double bonds of the identical monomers break and form single bonds with one another to form a polymer

→ no loss of atoms (simply monomers joining one another)

→ Naming: Add 'poly' in front of monomer used (for identical monomers) (styrene ⇒ poly(styrene) or polystyrene)

LO: → E.g. Polymer: Poly(ethene) | identical monomer: ethene | uses: cling film, plastic bags

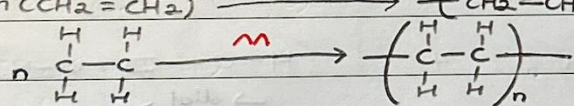


Equations:

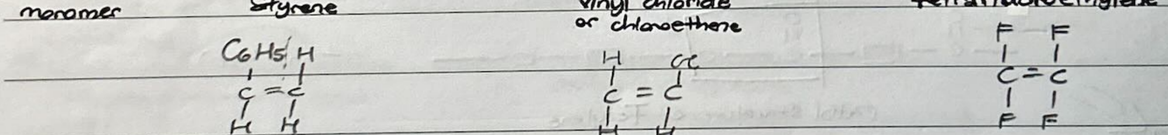
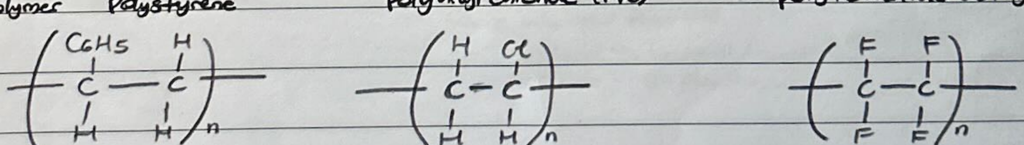
word → ethene —^^→ poly(ethene)

molecular formula → $n(CH_2 = CH_2) \xrightarrow{\wedge\wedge} -\!\left(CH_2 - CH_2\right)_n\!-$

structural formula →



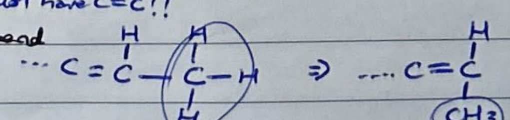
other addition polymers

monomer	Styrene	vinyl chloride or chloroethene	tetrafluoroethylene
			
addition polymer	Polystyrene	polyvinyl chloride (PVC)	polytetrafluoroethylene
			
uses	→ hard, light, brittle ↳ disposable containers (styrofoam)	↳ thin gloves, pipes, raincoats, flooring mats	→ non-stick, heat-resistant ↳ non-stick frying pans (teflon)

Reverse

join any two C atoms → form double bond

★ must have C=C!!



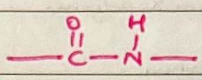
#2: Condensation Polymerisation → process of forming a large molecule by joining large number of monomers together and eliminating small molecules from the process.

~~↳ process that~~

– when monomers combine to form condensation polymers, small molecules are removed (eg water)

synthetic polymers from cond. polymerisation → polymers formed by two different monomers in alternate positions ⇒ –A—B—A—B—

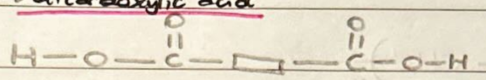
➜ ① Polyamide — nylon ← name.

– contains a large no. of amide linkage,  , or —CO—NH—

– uses: fishing lines, parachutes, sleeping bags, climbing ropes

monomers:

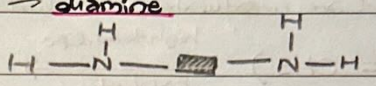
→ dicarboxylic acid (↗ 2 –COOH grps)



– see esterification for carboxy acids

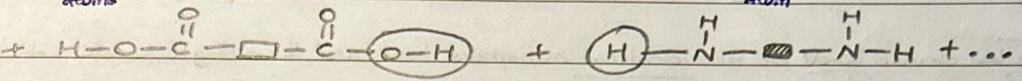
→ lose OH atoms at both ends (for —COOH)

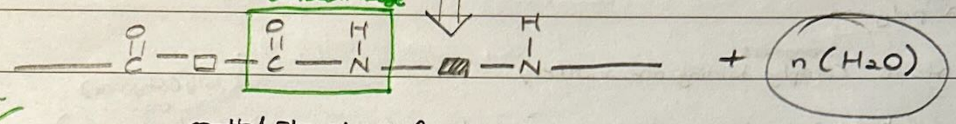
→ diamine (↗ 2 – NH_2 grps)



□, ▨ → long hydrocarbon chains

→ lose H atom at both ends (for —NH_2)





two monomers ~~joined tgt~~

Repeating unit

partial structure of nylon

water

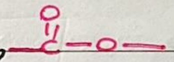
Reverse: ① Identify repeating unit

② Split into monomers (ends are same)

③ Add OH to C=O (since –COOH loses OH)

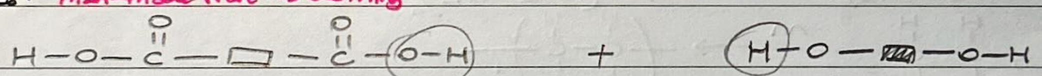
Add H to N–H (since –NH_2 loses H)

➜ #2: Polyester — terylene

– contains a large no. of ester linkage,  , or —COO—

– uses: man-made fibre → clothing

monomers:

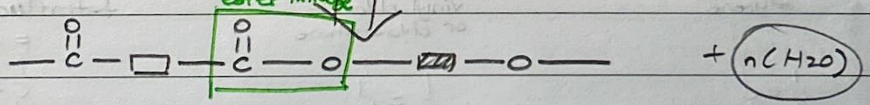


→ dicarboxylic acid (sim. to nylon)

↳ lose —OH at both ends

→ diol — 2 – OH grps

↳ lose —H at both ends



Repeating unit

partial structure of Terylene

Reverse: ①② ~~same~~ as nylon

③ Add OH to C=O (COOH)

Add H to O (OH)

PROBLEMS W SYNTHETIC PLASTICS

①: non-biodegradable

→ cannot be broken down easily by decomposers (eg bacteria) or by natural biological processes

↳ land pollution / (land-fills ↑) — use up valuable space

②: release poisonous carbon monoxide gas — see Geog / air quality (Ch 22?) — what's pollution??? — Bio

→ when burnt incompletely

↳ air pollution

RECYCLING PLASTICS

Physical — mechanical recycling

- does not change composition of waste.
- plastic waste is made into new products thru physical processes like melting, cooling.

Chemical

- involves chemical reactions.

→ CRACKING

- plastic waste broken into alkanes and alkenes
  - short-chain alkanes ↳ fuels
  - short-chain alkenes ↳ raw materials to produce new industrial products

→ Depolymerisation

- convert polymers back into monomers ↳ used to make other products
- for polyesters: acid hydrolysis
  ↳ polyester broken down in presence of an acid catalyst
  ↳ into dicarboxylic acids, diols

Issues related to recycling plastics

Environmental:

→ untreated wastewater generated from recycling plants discharged

↳ contaminate water bodies

↳ water pollution.

Economic:

→ expensive → transporting waste, sorting, cleaning waste

↳ requires machines, manpower, energy

→ not worthwhile to convert plastic waste into new products

↳ tend to be sold lower $ than virgin plastics

Social:

→ ppl find more convenient to discard plastic waste than sort for recycling

→ ppl not aware how to properly recycle plastic waste → binned waste may not be recycled eventually (sweet drink left ... food)