PHYSICAL SCIENCES

Grade12

TERM 4

Revision Booklet

TARGETED SUPPORT

Contents

A Message from the NECT

National Education Collaboration Trust (NECT)

Dear Teachers

This learning programme and training is provided by the National Education Collaboration Trust (NECT) on behalf of the Department of Basic Education (DBE)! We hope that this programme provides you with additional skills, methodologies and content knowledge that you can use to teach your learners more effectively.

What is NECT?

In 2012 our government launched the National Development Plan (NDP) as a way to eliminate poverty and reduce inequality by the year 2030. Improving education is an important goal in the NDP which states that 90% of learners will pass Maths, Science and languages with at least 50% by 2030. This is a very ambitious goal for the DBE to achieve on its own, so the NECT was established in 2015 to assist in improving education and to help the DBE reach the NDP goals.

The NECT has successfully brought together groups of relevant people so that we can work collaboratively to improve education. These groups include the teacher unions, businesses, religious groups, trusts, foundations and NGOs.

What are the Learning programmes?

One of the programmes that the NECT implements on behalf of the DBE is the 'District Development Programme'. This programme works directly with district officials, principals, teachers, parents and learners; you are all part of this programme!

The programme began in 2015 with a small group of schools called the Fresh Start Schools (FSS). Curriculum learning programmes were developed for Maths, Science and Language teachers in FSS who received training and support on their implementation. The FSS teachers remain part of the programme, and we encourage them to mentor and share their experience with other teachers.

The FSS helped the DBE trial the NECT learning programmes so that they could be improved and used by many more teachers. NECT has already begun this embedding process.

Everyone using the learning programmes comes from one of these groups; but you are now brought together in the spirit of collaboration that defines the manner in which the NECT works. Teachers with more experience using the learning programmes will deepen their knowledge and understanding, while some teachers will be experiencing the learning programmes for the first time.

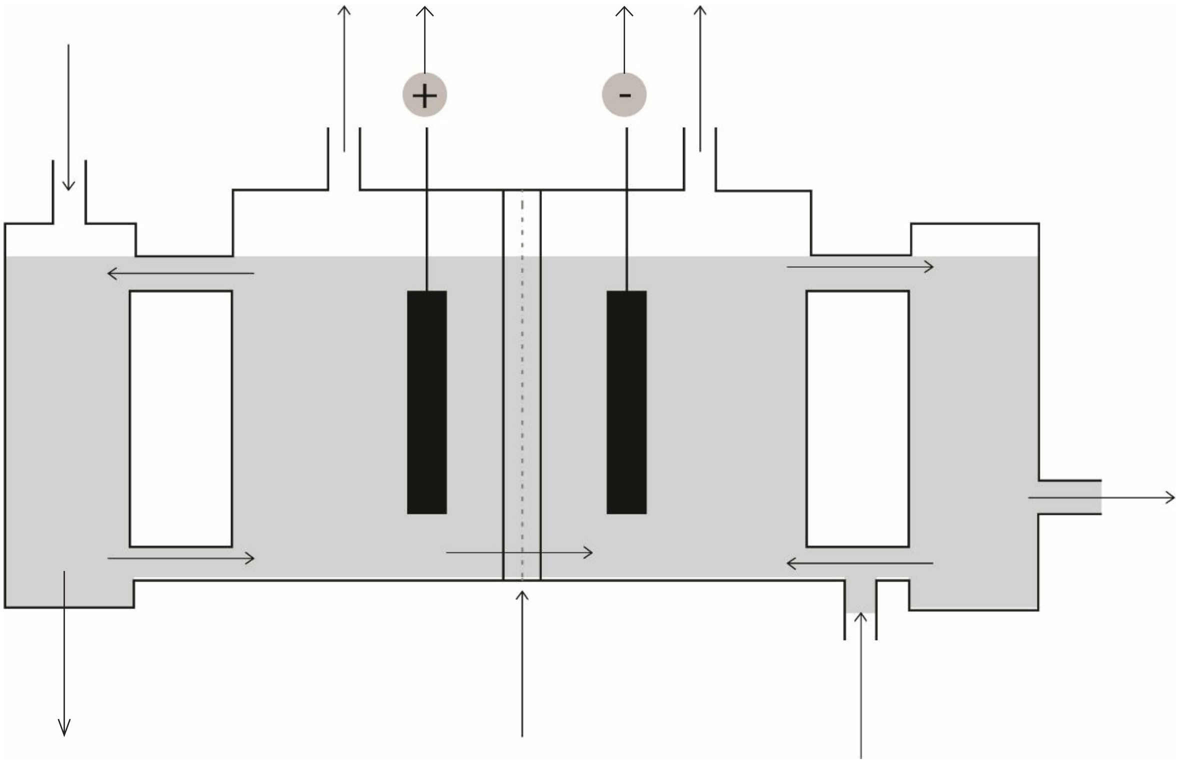
Let's work together constructively in the spirit of collaboration so that
we can help South Africa eliminate poverty and improve education!
www.nect.org.za

REVISION EXERCISES

Electrochemistry

MEMBRANE CELL

Provide labels for the diagram below.



____ (heading)

Write an equation for the reaction occurring at the anode.

Anode: ____

- The Na^+ ions move through the membrane into the cathode compartment.

Write an equation for the reaction occurring at the cathode.

Cathode: ____

- The Na^+ ions in the cathode compartment combine with the OH^- ions that are the product of the reduction half reaction. Write an equation to represent this.

____

- The membrane is selective to positive ions only, therefore:
    - no OH^- ions pass back into the anode compartment. If they did, they would undergo oxidation at the anode and O_2 (g) would be formed there, contaminating the production of Cl_2 (g).
    - no Cl^- ions pass into the cathode compartment. Therefore, no production of NaCl to mix with the NaOH.

ADVANTAGES:

List two advantages of the membrane cell.

-
-

DISADVANTAGES:

- Membranes are expensive.
- High purity brine is required.

USES OF PRODUCTS

HYDROGEN (H_2)

- making ammonia in the Haber process (NH_3).
- making margarine.

CHLORINE (Cl_2)

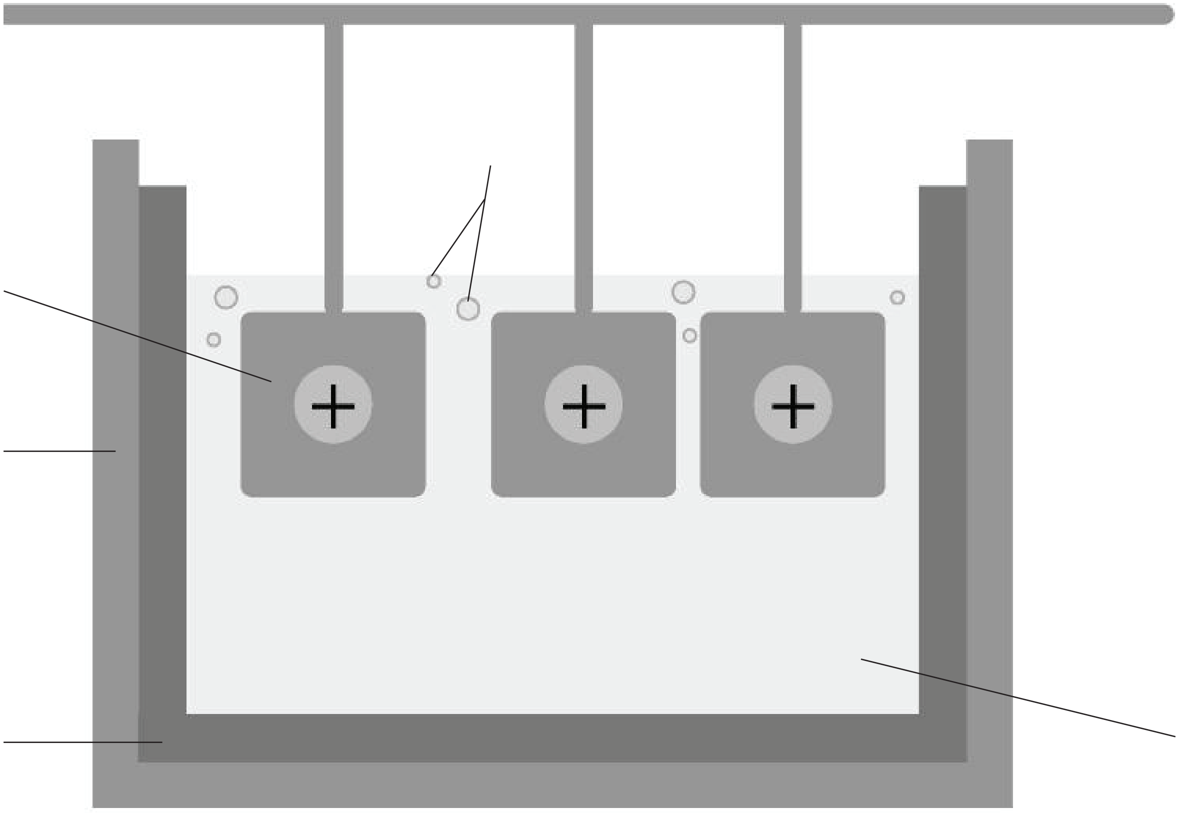
-
-
-
-
-
-
-

SODIUM HYDROXIDE (NaOH)

- making soap.
- making paper.
- making ceramics.

RECOVERY OF ALUMINIUM FROM BAUXITE

Provide labels for the diagram below.



____ (heading)

- Raw material = Bauxite. Write equations to show how bauxite becomes pure alumina.

____

- Cryolite is added to the alumina to lower its melting point. Write the equation for the reaction occurring at the cathode.

  Cathode: ____

- Molten aluminium is formed at the bottom of the compartment. Write the equation for the reaction occurring at the anode.

  Anode: ____

- O_2 bubbles form at the anodes, that then react with the graphite (C) anode. Write the equation for this additional reaction occurring at the anodes.

  ____

This reaction between the O_2 and the graphite anode is undesirable because:

a. it produces the greenhouse gas CO_2, that contributes to global warming.

b. it corrodes the graphite anodes, causing them to need replacing.

Write the net ionic reaction and overall net cell reaction.

Net ionic reaction: ____

Net reaction: ____

ENVIRONMENTAL ISSUES:

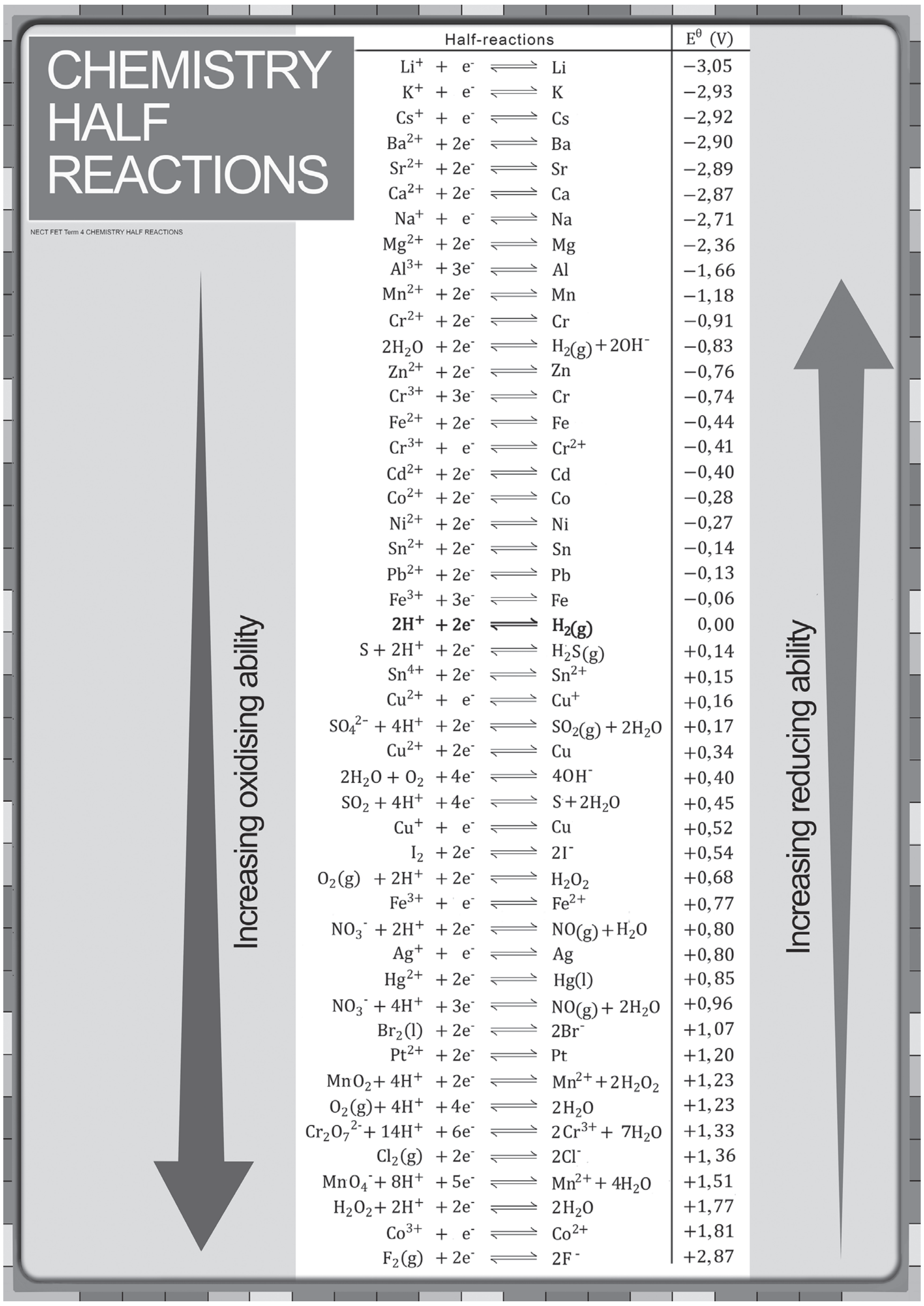
List three environmental issues.

-
-
-

USES OF ALUMINIUM:

- cans.
- ‘tin’ foil.
- window frames.
- aeroplane parts.

Highlight the relevant reactions for the two electrolytic cells above.



CHEMISTRY HALF REACTIONS

NECT FET Term 4 CHEMISTRY HALF REACTIONS

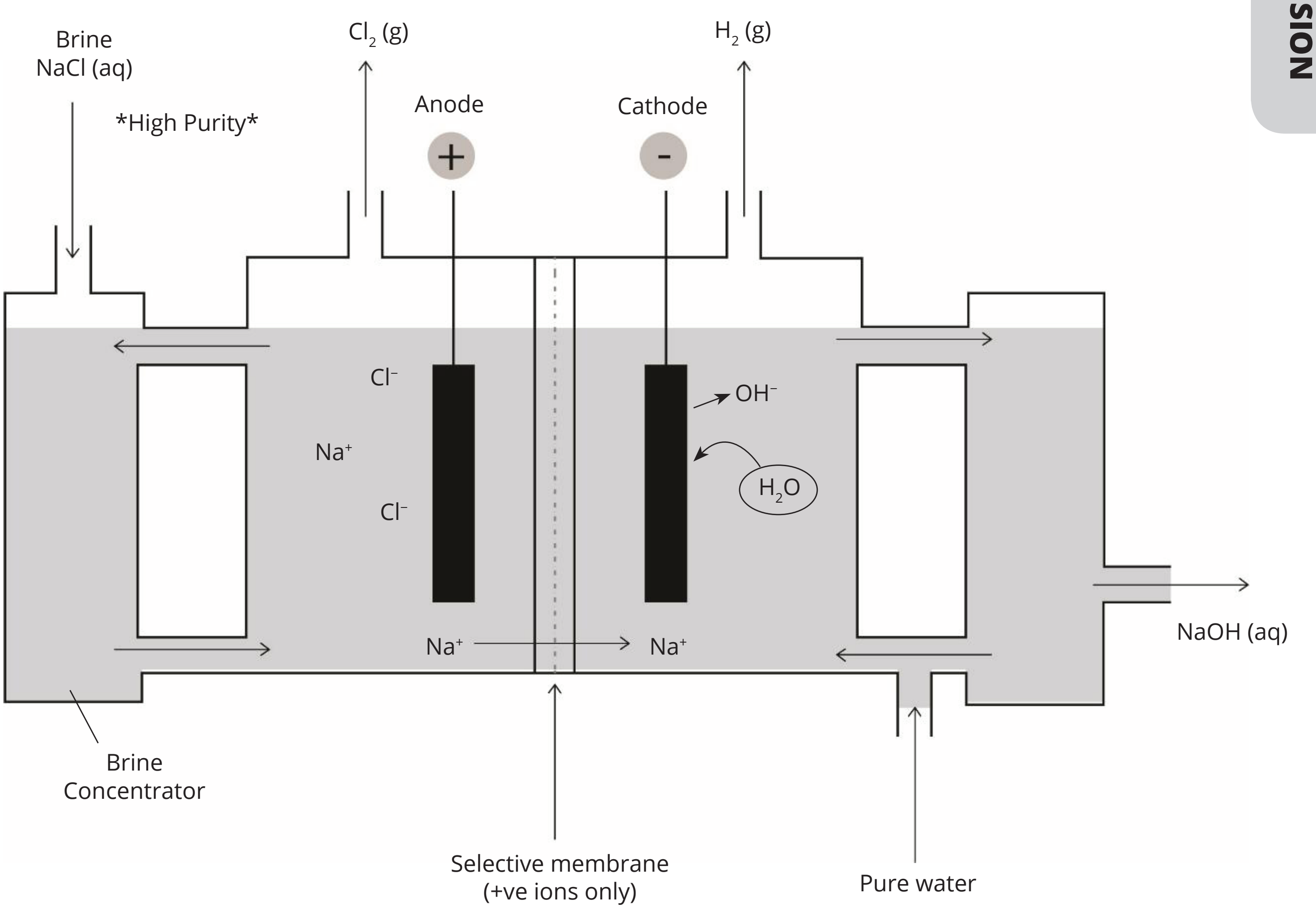
Half-reactions	E^θ (V)
$Li^+ + e^- \rightleftharpoons Li$	−3,05
$K^+ + e^- \rightleftharpoons K$	−2,93
$Cs^+ + e^- \rightleftharpoons Cs$	−2,92
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	−2,90
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	−2,89
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	−2,87
$Na^+ + e^- \rightleftharpoons Na$	−2,71
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2,36
$Al^{3+} + 3e^- \rightleftharpoons Al$	−1,66
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	−1,18
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	−0,91
$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	−0,83
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	−0,76
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	−0,74
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	−0,44
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	−0,41
$Cd^{2+} + 2e^- \rightleftharpoons Cd$	−0,40
$Co^{2+} + 2e^- \rightleftharpoons Co$	−0,28
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	−0,27
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	−0,14
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	−0,13
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	−0,06
$2H^+ + 2e^- \rightleftharpoons H_2(g)$	0,00
$S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$	+0,14
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+0,15
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0,16
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$	+0,17
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0,34
$2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$	+0,40
$SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$	+0,45
$Cu^+ + e^- \rightleftharpoons Cu$	+0,52
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0,54
$O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+0,68
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0,77
$NO_3^- + 2H^+ + 2e^- \rightleftharpoons NO(g) + H_2O$	+0,80
$Ag^+ + e^- \rightleftharpoons Ag$	+0,80
$Hg^{2+} + 2e^- \rightleftharpoons Hg(l)$	+0,85
$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$	+0,96
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-$	+1,07
$Pt^{2+} + 2e^- \rightleftharpoons Pt$	+1,20
$MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O_2$	+1,23
$O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1,33
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-$	+1,36
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1,51
$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1,77
$Co^{3+} + e^- \rightleftharpoons Co^{2+}$	+1,81
$F_2(g) + 2e^- \rightleftharpoons 2F^-$	+2,87

Increasing oxidising ability

Increasing reducing ability

MARKING GUIDELINES

MEMBRANE CELL



THE MEMBRANE CELL

Anode: $\mathbf{2Cl^- \rightarrow Cl_2 + 2e^-}$ **(oxidation half reaction)**

- The Na^+ ions move through the membrane into the cathode compartment.

Cathode: $\mathbf{2H_2O + 2e^- \rightarrow 2OH^- + H_2}$ **(reduction half reaction)**

- The Na^+ ions in the cathode compartment combine with the OH^- ions that are the product of the reduction half reaction.

  $\mathbf{Na^+(aq) + OH^-(aq) \rightarrow NaOH\ (aq)}$

- The membrane is selective to positive ions only, therefore:
  - no OH^- ions pass back into the anode compartment. If they did, they would undergo oxidation at the anode and O_2 (g) would be formed there, contaminating the production of Cl_2 (g).
  - no Cl^- ions pass into the cathode compartment. Therefore, no production of NaCl to mix with the NaOH.

ADVANTAGES:

- financially viable – lower total energy consumption than other methods.
- high purity of NaOH.

DISADVANTAGES:

- membranes are expensive.
- high purity brine is required.

USES OF PRODUCTS

HYDROGEN (H_2)

- making ammonia in the Haber process (NH_3).
- making margarine.

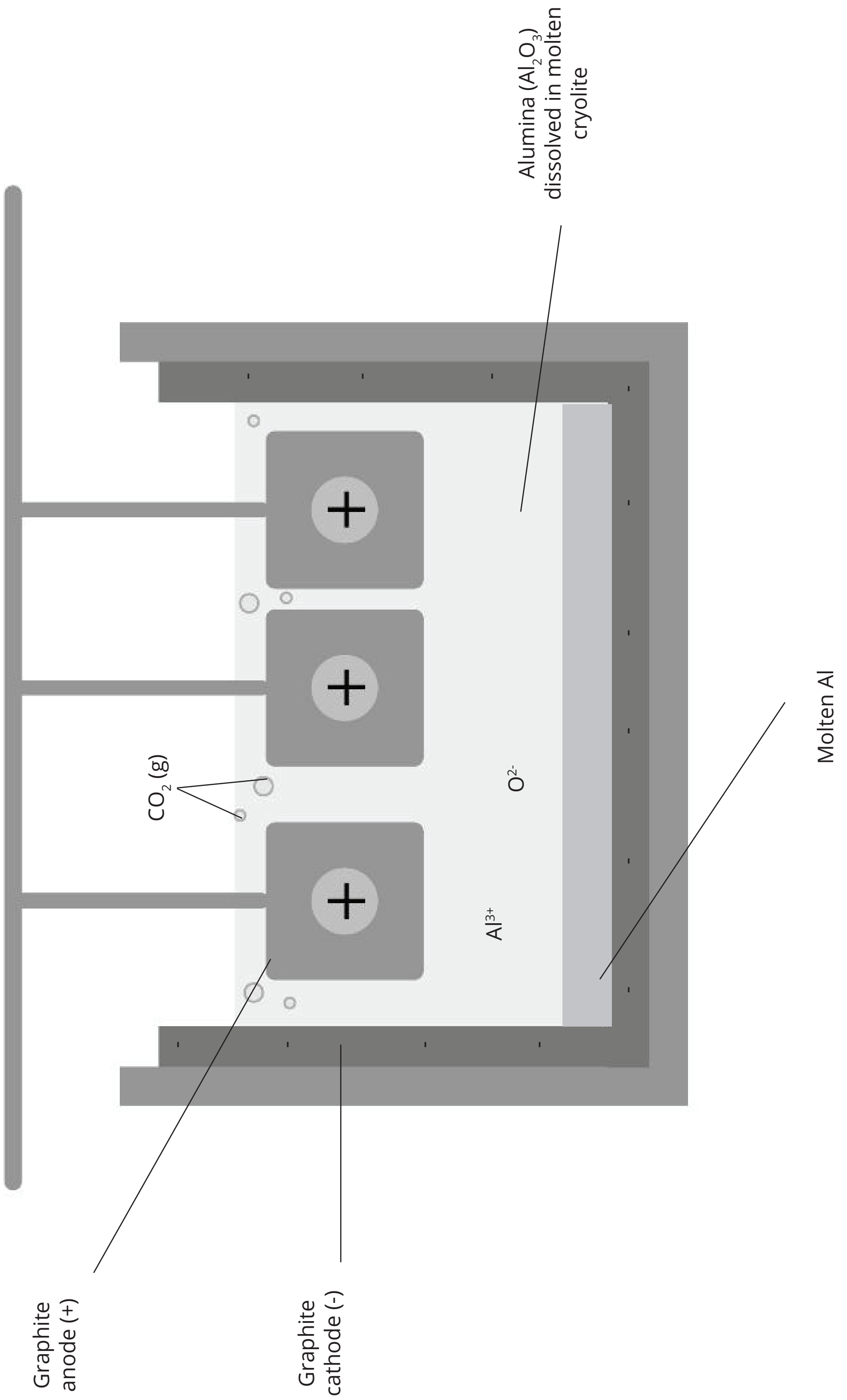
CHLORINE (Cl_2)

- killing bacteria in drinking water.
- killing bacteria in swimming pools.
- making bleach.
- making disinfectants.
- making hydrochloric acid (HCl).
- making PVC.
- making CFC's - limited production.

SODIUM HYDROXIDE (NaOH)

- making soap.
- making paper.
- making ceramics.

RECOVERY OF ALUMINIUM FROM BAUXITE



RECOVERY OF ALUMINIUM FROM ALUMINA

- Raw material = Bauxite.

  Bauxite (impure Al_2O_3) $\xrightarrow{NaOH}$ $Al(OH)_3$ (aq) $\xrightarrow{1\ 000°C}$ Al_2O_3 (pure alumina)

- Cryolite is added to the alumina to lower its melting point.

  Cathode: **$Al^{3+} + 3e^- \rightarrow Al$ (x4) (reduction half reaction)**

- Molten aluminium is formed at the bottom of the compartment.

  Anode: **$2O^{2-} \rightarrow O_2 + 4e^-$ (x3) (oxidation half reaction) **Not on data sheet****

- O_2 bubbles form at the anode, that then react with the graphite (C) anode:

  Additional reaction: $C + O_2 \rightarrow CO_2$

This reaction between the O_2 and the graphite anode is undesirable because:

a. it produces the greenhouse gas CO_2, that contributes to global warming.

b. it corrodes the graphite anodes, causing them to need replacing.

Net ionic reaction: **$4Al^{3+} + 6O^{2-} \rightarrow 4Al + 3O_2$**

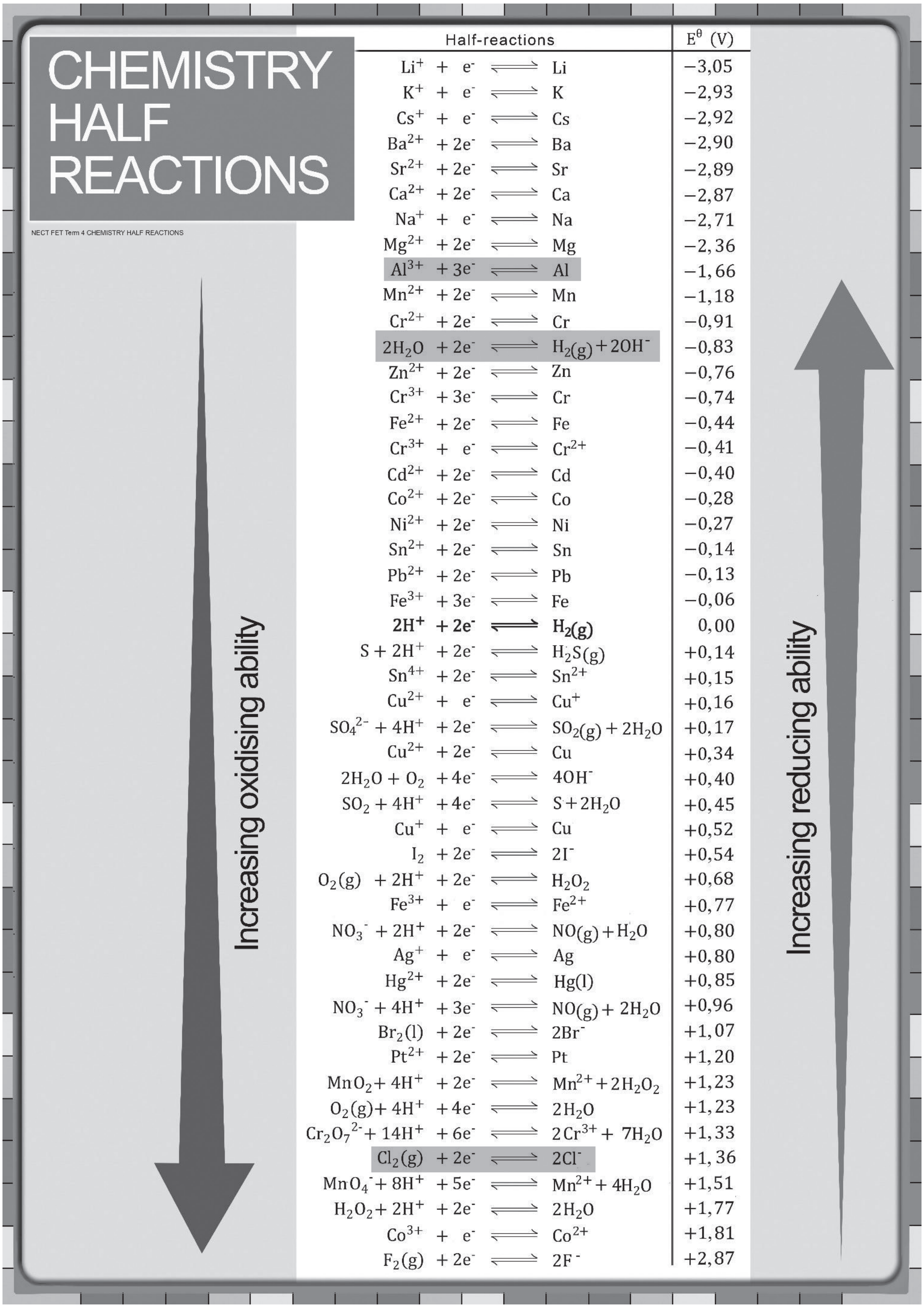
Net reaction: **$2Al_2 O_3 \rightarrow 4Al + 3O_2$**

ENVIRONMENTAL ISSUES:

- uses a large amount of electricity. This burns fossil fuels.
- CO_2 – greenhouse gas – global warming.
- left over material gets pumped into rivers – red mud – kills plants and fish.

USES OF ALUMINIUM:

- cans.
- 'tin' foil.
- window frames.
- aeroplane parts.



CHEMISTRY HALF REACTIONS

NECT FET Term 4 CHEMISTRY HALF REACTIONS

Half-reactions	E^θ (V)
$Li^+ + e^- \rightleftharpoons Li$	−3,05
$K^+ + e^- \rightleftharpoons K$	−2,93
$Cs^+ + e^- \rightleftharpoons Cs$	−2,92
$Ba^{2+} + 2e^- \rightleftharpoons Ba$	−2,90
$Sr^{2+} + 2e^- \rightleftharpoons Sr$	−2,89
$Ca^{2+} + 2e^- \rightleftharpoons Ca$	−2,87
$Na^+ + e^- \rightleftharpoons Na$	−2,71
$Mg^{2+} + 2e^- \rightleftharpoons Mg$	−2,36
$Al^{3+} + 3e^- \rightleftharpoons Al$	−1,66
$Mn^{2+} + 2e^- \rightleftharpoons Mn$	−1,18
$Cr^{2+} + 2e^- \rightleftharpoons Cr$	−0,91
$2H_2O + 2e^- \rightleftharpoons H_2(g) + 2OH^-$	−0,83
$Zn^{2+} + 2e^- \rightleftharpoons Zn$	−0,76
$Cr^{3+} + 3e^- \rightleftharpoons Cr$	−0,74
$Fe^{2+} + 2e^- \rightleftharpoons Fe$	−0,44
$Cr^{3+} + e^- \rightleftharpoons Cr^{2+}$	−0,41
$Cd^{2+} + 2e^- \rightleftharpoons Cd$	−0,40
$Co^{2+} + 2e^- \rightleftharpoons Co$	−0,28
$Ni^{2+} + 2e^- \rightleftharpoons Ni$	−0,27
$Sn^{2+} + 2e^- \rightleftharpoons Sn$	−0,14
$Pb^{2+} + 2e^- \rightleftharpoons Pb$	−0,13
$Fe^{3+} + 3e^- \rightleftharpoons Fe$	−0,06
$2H^+ + 2e^- \rightleftharpoons H_2(g)$	0,00
$S + 2H^+ + 2e^- \rightleftharpoons H_2S(g)$	+0,14
$Sn^{4+} + 2e^- \rightleftharpoons Sn^{2+}$	+0,15
$Cu^{2+} + e^- \rightleftharpoons Cu^+$	+0,16
$SO_4^{2-} + 4H^+ + 2e^- \rightleftharpoons SO_2(g) + 2H_2O$	+0,17
$Cu^{2+} + 2e^- \rightleftharpoons Cu$	+0,34
$2H_2O + O_2 + 4e^- \rightleftharpoons 4OH^-$	+0,40
$SO_2 + 4H^+ + 4e^- \rightleftharpoons S + 2H_2O$	+0,45
$Cu^+ + e^- \rightleftharpoons Cu$	+0,52
$I_2 + 2e^- \rightleftharpoons 2I^-$	+0,54
$O_2(g) + 2H^+ + 2e^- \rightleftharpoons H_2O_2$	+0,68
$Fe^{3+} + e^- \rightleftharpoons Fe^{2+}$	+0,77
$NO_3^- + 2H^+ + 2e^- \rightleftharpoons NO(g) + H_2O$	+0,80
$Ag^+ + e^- \rightleftharpoons Ag$	+0,80
$Hg^{2+} + 2e^- \rightleftharpoons Hg(l)$	+0,85
$NO_3^- + 4H^+ + 3e^- \rightleftharpoons NO(g) + 2H_2O$	+0,96
$Br_2(l) + 2e^- \rightleftharpoons 2Br^-$	+1,07
$Pt^{2+} + 2e^- \rightleftharpoons Pt$	+1,20
$MnO_2 + 4H^+ + 2e^- \rightleftharpoons Mn^{2+} + 2H_2O_2$	+1,23
$O_2(g) + 4H^+ + 4e^- \rightleftharpoons 2H_2O$	+1,23
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightleftharpoons 2Cr^{3+} + 7H_2O$	+1,33
$Cl_2(g) + 2e^- \rightleftharpoons 2Cl^-$	+1,36
$MnO_4^- + 8H^+ + 5e^- \rightleftharpoons Mn^{2+} + 4H_2O$	+1,51
$H_2O_2 + 2H^+ + 2e^- \rightleftharpoons 2H_2O$	+1,77
$Co^{3+} + e^- \rightleftharpoons Co^{2+}$	+1,81
$F_2(g) + 2e^- \rightleftharpoons 2F^-$	+2,87

Organic Reactions

SUBSTITUTION REACTIONS

- This is a reaction in which one atom or group of atoms is replaced by another.
- Saturated compounds undergo substitution reactions.
- 2 reactants → 2 products.

A. ALKANES TO HALOALKANES

Reaction conditions:

- UV light or heat.
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. methane + chlorine → ____________________ + ________________

B. HALOALKANES TO ALCOHOLS

Reaction conditions:

- Heat under reflux in an aqueous alkali solution of KOH(aq) or NaOH(aq).
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. bromoethane + potassium hydroxide → ________________ + ____________

C. ALCOHOLS TO HALOALKANES

Reaction conditions:

- High temperatures.
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. ethanol + potassium bromide → __________________ + ________________

ADDITION REACTIONS

- This is a reaction that involves the adding of atoms to a compound as a result of the breaking of a double/triple bond.
- Unsaturated compounds undergo addition reactions.
- 2 reactants → 1 product.

A. HYDROGENATION (ADDING OF ______________)

Reaction conditions:

- alkene dissolved in a non-polar solvent.
- catalyst Pt, Pd, Ni in a hydrogen atmosphere.

  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. ethene + hydrogen → ______________

B. HALOGENATION (ADDING OF ______________________)

Reaction conditions:

- room temperature.

  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. propene + bromine → ______________________

N.B. This reaction can be used as a test for ____________________.
Describe the test below.

____

____

____

____

____

C. HYDROHALOGENATION (ADDING OF ______________ AND ______________)

Reaction conditions:

- no water may be present.
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. ethene + hydrogen chloride → ____________________________

D. HYDRATION (ADDING OF ___________)

Reaction conditions:

- steam.
- catalyst. e.g. H_3PO_4.
- high pressure (60 atm).
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. propene + steam → ___________________________

ELIMINATION REACTIONS

- This reaction involves the removal of atoms from a compound as a result of the formation of a double/triple bond.
- Saturated compounds undergo elimination reactions.
- 1 reactants → 2 products.

A. DEHYDRATION OF ALCOHOLS (REMOVAL OF __________)

Reaction conditions:

- heating of alcohol with H_2SO_4 or H_3PO_4 (dehydrating agents).
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. ethanol → ____________ + ____________

B. DEHYDROHALOGENATION (REMOVAL OF __________ AND __________)

Reaction conditions:

- hot, concentrated solution of NaOH or KOH in an ethanol solvent i.e. hot ethanolic KOH or NaOH.
  Complete the example below using a word equation, structural formulae and then molecular formulae.

  e.g. bromoethane → ________________ + ________________

C. CRACKING

Reaction conditions:

- Thermal cracking – high pressures and temperatures. No catalyst.
- Catalytic cracking – lower temperatures and pressures. Catalyst.

COMBUSTION REACTIONS

Because they contain such a high carbon percentage, all organic compounds undergo combustion (burning) easily.

GENERAL EQUATION:

organic compound + oxygen → carbon dioxide + water

$$X + O_2 \rightarrow CO_2 + H_2O$$

Hint: Balance the elements in this order: C, then H, then O.

e.g. Combustion of propane.

e.g. Combustion of ethanol.

e.g. Combustion of butane.

e.g. Combustion of hexane.

N.B. Alkanes burn with a cleaner flame than their corresponding alkene. Prove this by comparing the percentage of carbon per molecule of each.

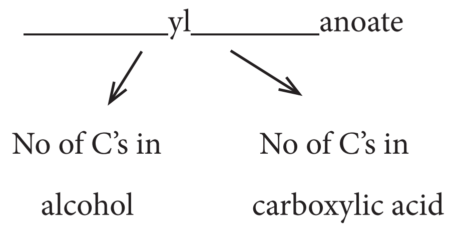
ESTERIFICATION REACTIONS

- Esters are known for their pleasant, characteristic smells. Therefore they are used for perfumes, shampoos, milkshake flavours etc.
- The reaction requires the presence of concentrated H_2SO_4 (sulfuric acid). It acts as:
  - a catalyst.
  - a dehydrating agent.

GENERAL EQUATION:

alcohol + carboxylic acid → ester + water

Naming an ester:



For all the examples below, complete the word equation and then write the equation using structural formulae.

e.g. methanol + ethanoic acid → ____________________ + _________________

e.g. ethanol + propanoic acid → ____________________ + __________________

e.g. _________________ + ___________________ → propylethanoate + ____________

e.g. Draw the structural formulae for:

1. ethylbutanoate.
2. butylpropanoate.

ISOMERS

Isomers are compounds that have the same molecular formula but different structural formulae.

1. **Chain isomers**

   Isomers are formed by the creation of branching chains.
   e.g. Draw structural formulae for all the chain isomers of C_6H_{14}.

2. **Positional isomers**

   Isomers that are formed by moving the position of a functional group.
   Draw structural formulae for all the positional isomers below.

   e.g. Positional isomers of C_4H_8.

   e.g. Positional isomers of C_3H_7OH.

   e.g. Positional isomers of $C_3H_6O_2$.

3. **Functional group isomers**

   Isomers that belong to different homologous series.
   Draw structural formulae for all the functional group isomers.

   e.g. Functional group isomers of C_3H_6O.

   e.g. Functional group isomers of $C_3H_6O_2$.

MARKING GUIDELINES

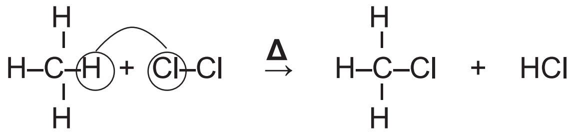
SUBSTITUTION REACTIONS

- This is a reaction in which one atom or group of atoms is replaced by another.
- Saturated compounds undergo substitution reactions.
- 2 reactants → 2 products.

A. ALKANES TO HALOALKANES

Reaction conditions:

- UV light or heat.
  e.g. methane + chlorine $\xrightarrow{\Delta}$ chloromethane + hydrogen chloride



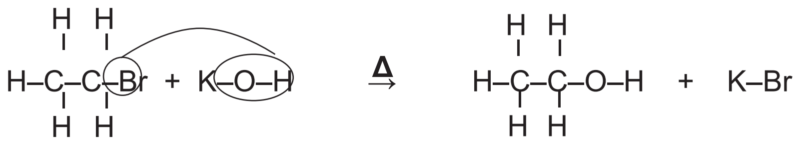
$$CH_4 + Cl_2 \xrightarrow{\Delta} CH_3Cl + HCl$$

B. HALOALKANES TO ALCOHOLS (HYDROLYSIS)

Reaction conditions:

- Heat under reflux in an aqueous alkali solution of KOH (aq) or NaOH (aq).

  e.g. bromoethane + potassium hydroxide $\xrightarrow{\Delta}$ ethanol + potassium bromide



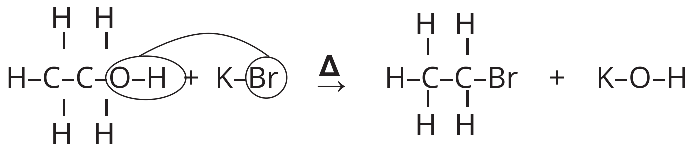
$$C_2H_5Br + KOH \xrightarrow{\Delta} C_2H_5OH + KBr$$

Note: Water can be used instead of the base but the reaction will be very slow.

C. ALCOHOLS TO HALOALKANES

Reaction conditions:

- High temperatures.
  e.g. ethanol + potassium bromide $\xrightarrow{\Delta}$ bromoethane + potassium hydroxide



$$C_2H_5OH + KBr \xrightarrow{\Delta} C_2H_5Br + KOH$$

ADDITION REACTIONS

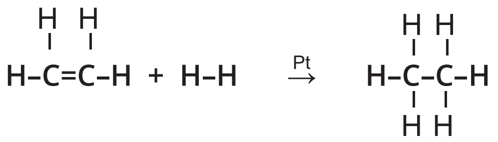
- This is a reaction that involves the adding of atoms to a compound as a result of the breaking of a double/triple bond.
- Unsaturated compounds undergo addition reactions.
- 2 reactants → 1 product.

A. HYDROGENATION (ADDING OF HYDROGEN) (H_2)

Reaction conditions:

- alkene dissolved in a non-polar solvent.
- catalyst Pt, Pd, Ni in an hydrogen atmosphere.

e.g. ethene + hydrogen $\xrightarrow{Pt}$ ethane



$$H{-}\overset{H}{\overset{|}{C}}{=}\overset{H}{\overset{|}{C}}{-}H + H{-}H \xrightarrow{Pt} H{-}\underset{\underset{H}{|}}{\overset{H}{\overset{|}{C}}}{-}\underset{\underset{H}{|}}{\overset{H}{\overset{|}{C}}}{-}H$$

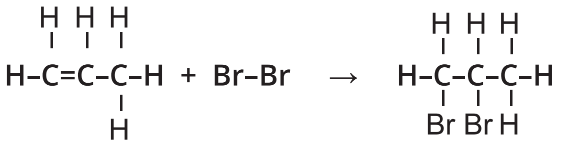
$$C_2H_4 + H_2 \xrightarrow{Pt} C_2H_6$$

B. HALOGENATION (ADDING OF A HALOGEN (Cl_2, Br_2, I_2))

Reaction conditions:

- Room temperature.

e.g. propene + bromine → 1, 2 dibromopropane



$$H{-}\overset{H}{\overset{|}{C}}{=}\overset{H}{\overset{|}{C}}{-}\underset{\underset{H}{|}}{\overset{H}{\overset{|}{C}}}{-}H + Br{-}Br \rightarrow H{-}\underset{\underset{Br}{|}}{\overset{H}{\overset{|}{C}}}{-}\underset{\underset{Br}{|}}{\overset{H}{\overset{|}{C}}}{-}\underset{\underset{H}{|}}{\overset{H}{\overset{|}{C}}}{-}H$$

$$C_3H_6 + Br_2 \rightarrow C_3H_6Br_2$$

N.B. This reaction can be used as a test for: unsaturation.

Br_2 added to any unsaturated compound readily undergoes addition.

Orange/brown colour of Br_2 goes colourless.

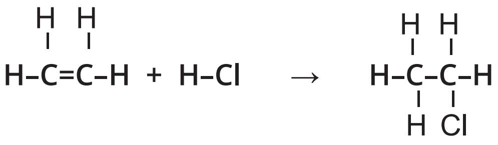
Orange colour remains if added to a saturated compound.

C. HYDROHALOGENATION (ADDING OF HYDROGEN AND A HALOGEN)

Reaction conditions:

- No water may be present. (During addition of HX to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The X atom attaches to the more substituted C atom).

  e.g. ethene + hydrogen chloride → chloroethane



$$H-\overset{H}{C}=\overset{H}{C}-H + H-Cl \rightarrow H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{Cl}{C}}-H$$

$$C_2H_4 + HCl \rightarrow C_2H_5Cl$$

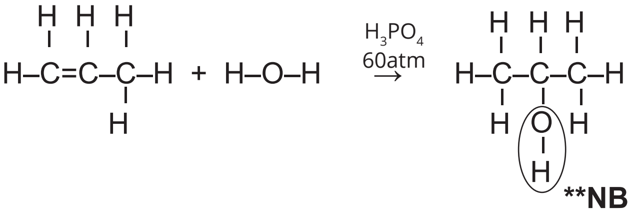
D. HYDRATION (ADDING OF WATER, FORMS AN ALCOHOL)

Reaction conditions:

- steam.
- catalyst e.g. H_3PO_4.
- high pressure (60 atm).

(During addition of H_2O to unsaturated hydrocarbons, the H atom attaches to the C atom already having the greater number of H atoms. The OH group attaches to the more substituted C-atom).

e.g. propene + steam $\xrightarrow{\substack{H_3PO_4\\60atm}}$ propan-2-ol



$$H-\overset{H}{C}=\overset{H}{C}-\overset{H}{\underset{H}{C}}-H + H-O-H \xrightarrow{\substack{H_3PO_4\\60atm}} H-\overset{H}{\underset{H}{C}}-\overset{H}{\underset{OH}{C}}-\overset{H}{\underset{H}{C}}-H$$

**NB

$$C_3H_6 + H_2O \xrightarrow{\substack{H_3PO_4\\60atm}} C_3H_7OH$$

ELIMINATION REACTIONS

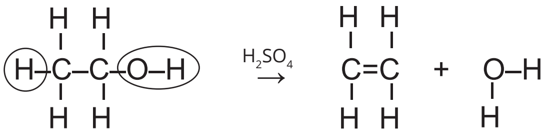
- This reaction involves the removal of atoms from a compound as a result of the formation of a double/triple bond.
- Saturated compounds undergo addition reactions.
- 1 reactants → 2 products.

A. DEHYDRATION OF ALCOHOLS (REMOVAL OF WATER)

Reaction conditions:

- Heating of alcohol with H_2SO_4 or H_3PO_4 (dehydrating agents).

- e.g. ethanol $\xrightarrow{H_2SO_4}$ ethene + water



$$C_2H_5OH \xrightarrow{H_2SO_4} C_2H_4 + H_2O$$

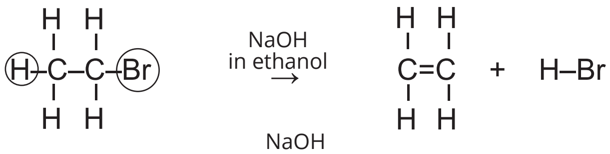
B. DEHYDROHALOGENATION (REMOVAL OF HYDROGEN AND A HALOGEN)

Reaction conditions:

- hot, concentrated solution of NaOH or KOH in an ethanol solvent.

(If more than one elimination product is possible, the major product is the one where the H atom is removed from the C atom with the least number of H atoms).

e.g. bromoethane $\xrightarrow{\text{NaOH in ethanol}}$ ethene + hydrogen bromide



$$C_2H_5Br \xrightarrow{\text{NaOH in ethanol}} C_2H_4 + HBr$$

C. CRACKING

Reaction conditions:

- thermal cracking – high pressures and temperatures. No catalyst.
- catalytic cracking – lower temperatures and pressures. Catalyst.

COMBUSTION REACTIONS

Because they contain such a high carbon percentage, all organic compounds undergo combustion (burning) easily.

GENERAL EQUATION:

organic compound + oxygen → carbon dioxide + water + energy

$$X + O_2 \rightarrow CO_2 + H_2O$$

Hint: Balance the elements in this order: C, then H, then O.

e.g. Combustion of propane.

$$C_3H_8 + \underline{5}O_2 \rightarrow \overbrace{\overset{6}{\underline{3}CO_2} + \overset{4}{\underline{4}H_2O}}^{10}$$

e.g. Combustion of ethanol.

$$C_2H_5\enclose{circle}{OH} + \underline{3}O_2 \rightarrow \overbrace{\overset{4}{\underline{2}CO_2} + \overset{3}{\underline{3}H_2O}}^{7}$$

e.g. Combustion of butane.

(x2)

$$C_4H_{10} + \frac{13}{2}O_2 \rightarrow \overbrace{\overset{8}{\underline{4}CO_2} + \overset{5}{\underline{5}H_2O}}^{13}$$

$$\underline{2}C_4H_{10} + \underline{13}O_2 \rightarrow \underline{8}CO_2 + \underline{10}H_2O$$

e.g. Combustion of hexane.

(x2)

$$C_6H_{14} + \frac{19}{2}O_2 \rightarrow \overbrace{\overset{12}{\underline{6}CO_2} + \overset{7}{\underline{7}H_2O}}^{19}$$

$$\underline{2}C_6H_{14} + \underline{19}O_2 \rightarrow \underline{12}CO_2 + \underline{14}H_2O$$

N.B. Alkanes burn with a cleaner flame than their corresponding alkene. Prove this by comparing the percentage of carbon per molecule of each.

Ethane: C_2H_6	Ethene: C_2H_4
$\% C = \frac{24}{30} \times 100$	$\% C = \frac{24}{28} \times 100$
$= 80\%$	$= 85{,}71\%$

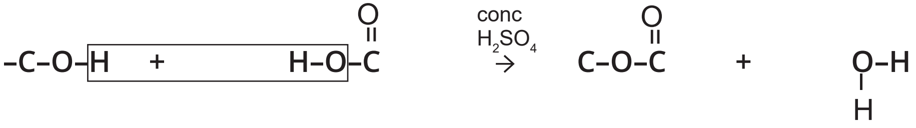
The higher carbon content of ethene means a sootier flame.

ESTERIFICATION REACTIONS

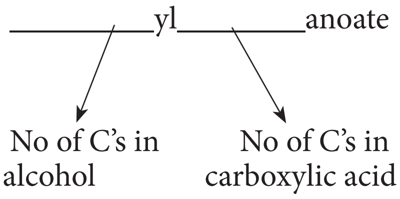
- Esters are known for their pleasant, characteristic smells. Therefore they are used for perfumes, shampoos, milkshake flavours etc.
- The reaction requires the presence of concentrated H_2SO_4 (sulfuric acid). It acts as:
  - a catalyst and
  - a dehydrating agent.

GENERAL EQUATION:

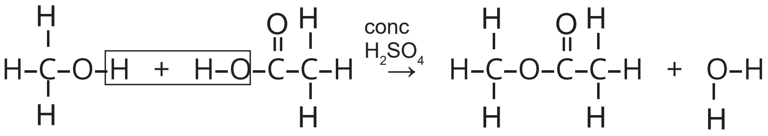
alcohol + carboxylic acid $\xrightarrow{\text{conc } H_2SO_4}$ ester + water



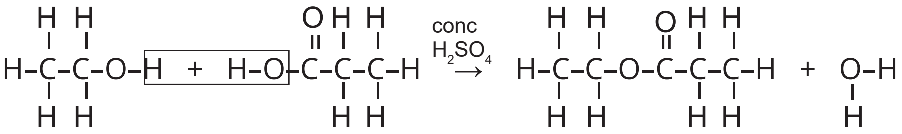
NAMING AN ESTER:



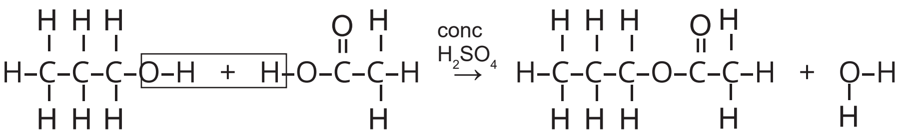
e.g. methanol + ethanoic acid → methylethanoate + water



e.g. ethanol + propanoic acid → ethylproponoate + water

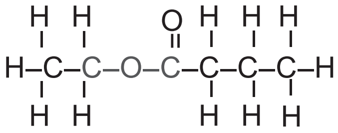


e.g. propanol + ethanoic acid → propylethanoate + water



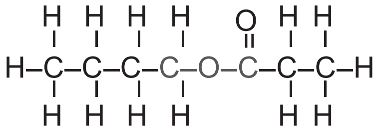
e.g. Draw the structural formulae for:

1. ethylbutanoate



$$\mathrm{H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H}$$

2. butylpropanoate



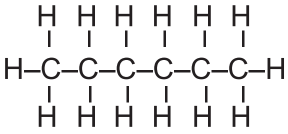
$$\mathrm{H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-\overset{O}{\overset{\|}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H}$$

ISOMERS

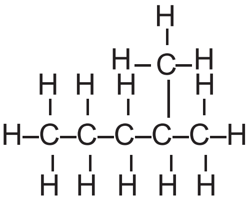
Isomers are compounds that have the same molecular formula but different structural formulae.

1. Chain isomers

Isomers are formed by the creation of branching chains.
e.g. Chain isomers of C_6H_{14} hexane.



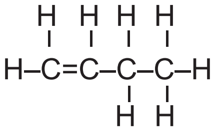
hexane



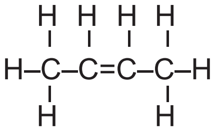
2-methylpentane

2. Positional isomers

Isomers that are formed by moving the position of a functional group.
e.g. Positional isomers of C_4H_8.

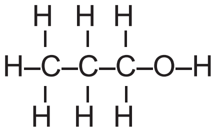


butene

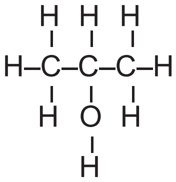


but-2-ene

e.g. Positional isomers of C_3H_7OH.

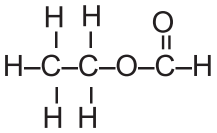


propanol

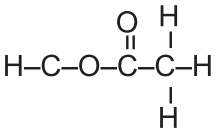


propan-2-ol

e.g. Positional isomers of $C_3H_6O_2$ (ester).



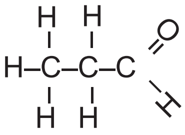
ethylmethanoate



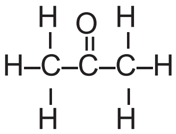
methylethanoate

3. Functional group isomers

Isomers that belong to different homologous series.
e.g. Functional group isomers of C_3H_6O.

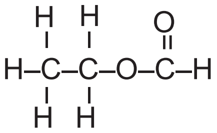


propanal

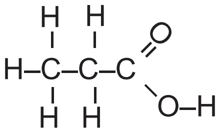


propanone

e.g. Functional group isomers of $C_3H_6O_2$.



ethylmethanoate



propanoic acid

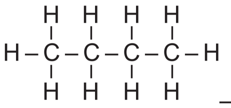
Flow Diagram

HYDROCARBONS

ALKANES

- General formula: ________________
- Functional group: ________________
- Saturated

e.g.



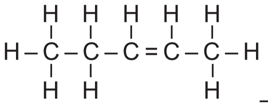
$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

____

ALKENES

- General formula: ________________
- Functional group: ________________
- Unsaturated

e.g.



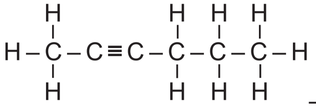
$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\overset{H}{C}=\overset{H}{C}-\underset{H}{\overset{H}{C}}-H$$

____

ALKYNES

- General formula: ________________
- Functional group: ________________
- Unsaturated

e.g.



$$H-\underset{H}{\overset{H}{C}}-C\equiv C-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

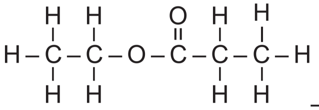
____

ESTERS

- Functional group: ________________

  Alcohol + Carboxylic Acid → Ester + Water

e.g.



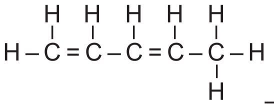
$$H-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-O-\overset{O}{\overset{\parallel}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-H$$

____

DIENES

- General formula: ________________
- 2 Double bonds

e.g.



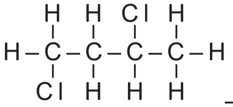
$$H-\overset{H}{C}=\overset{H}{C}-\overset{H}{C}=\overset{H}{C}-\underset{H}{\overset{H}{C}}-H$$

____

ALKYL HALIDES

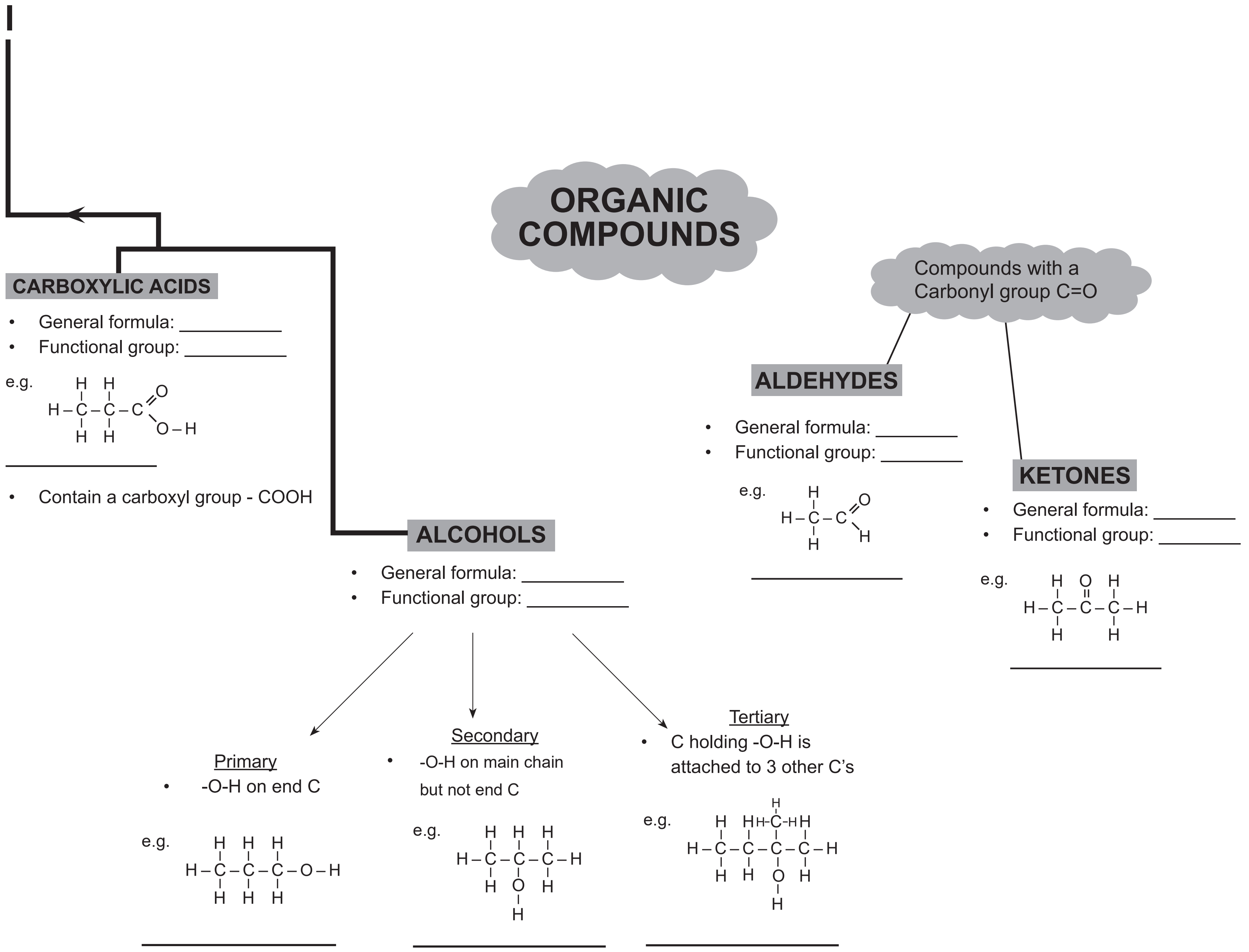
- Functional group: ________________

e.g.



$$H-\underset{Cl}{\overset{H}{C}}-\underset{H}{\overset{H}{C}}-\underset{H}{\overset{Cl}{C}}-\underset{H}{\overset{H}{C}}-H$$

____



ORGANIC COMPOUNDS

CARBOXYLIC ACIDS

- General formula: __________
- Functional group: __________

e.g.

____

- Contain a carboxyl group - COOH

ALCOHOLS

- General formula: __________
- Functional group: __________

Primary

- -O-H on end C

e.g.

____

Secondary

- -O-H on main chain but not end C

e.g.

____

Tertiary

- C holding -O-H is attached to 3 other C's

e.g.

____

Compounds with a Carbonyl group C=O

ALDEHYDES

- General formula: ________
- Functional group: ________

e.g.

____

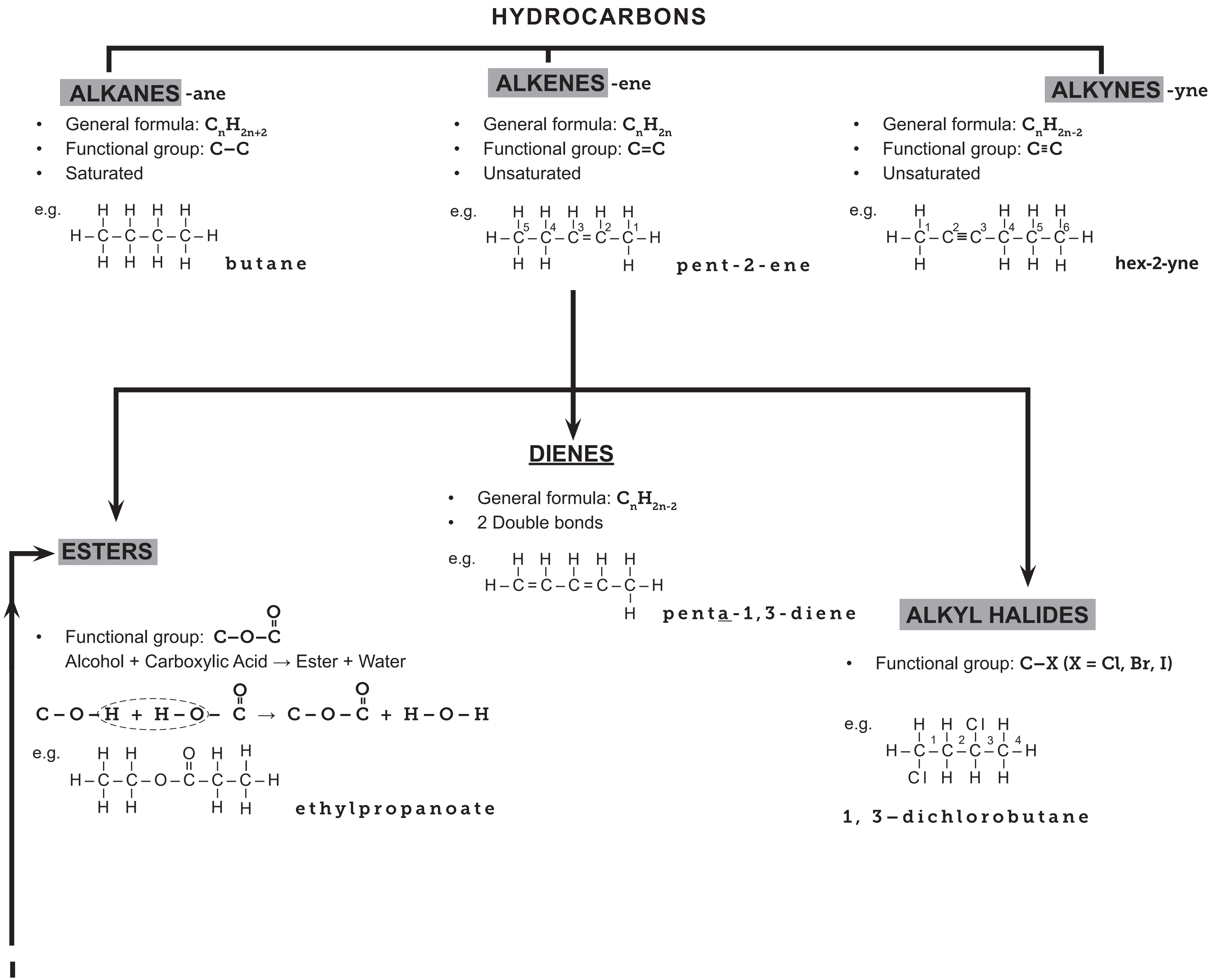
KETONES

- General formula: ________
- Functional group: ________

e.g.

____

MARKING GUIDELINES



HYDROCARBONS

ALKANES -ane

- General formula: C_nH_{2n+2}
- Functional group: **C–C**
- Saturated

e.g.

butane

ALKENES -ene

- General formula: C_nH_{2n}
- Functional group: **C=C**
- Unsaturated

e.g.

pent-2-ene

ALKYNES -yne

- General formula: C_nH_{2n-2}
- Functional group: **C≡C**
- Unsaturated

e.g.

hex-2-yne

DIENES

- General formula: C_nH_{2n-2}
- 2 Double bonds

e.g.

penta-1,3-diene

ESTERS

- Functional group: $C{-}O{-}\overset{O}{\overset{\|}{C}}$

Alcohol + Carboxylic Acid → Ester + Water

$$C-O-H + H-O-\overset{O}{\overset{\|}{C}} \rightarrow C-O-\overset{O}{\overset{\|}{C}} + H-O-H$$

e.g.

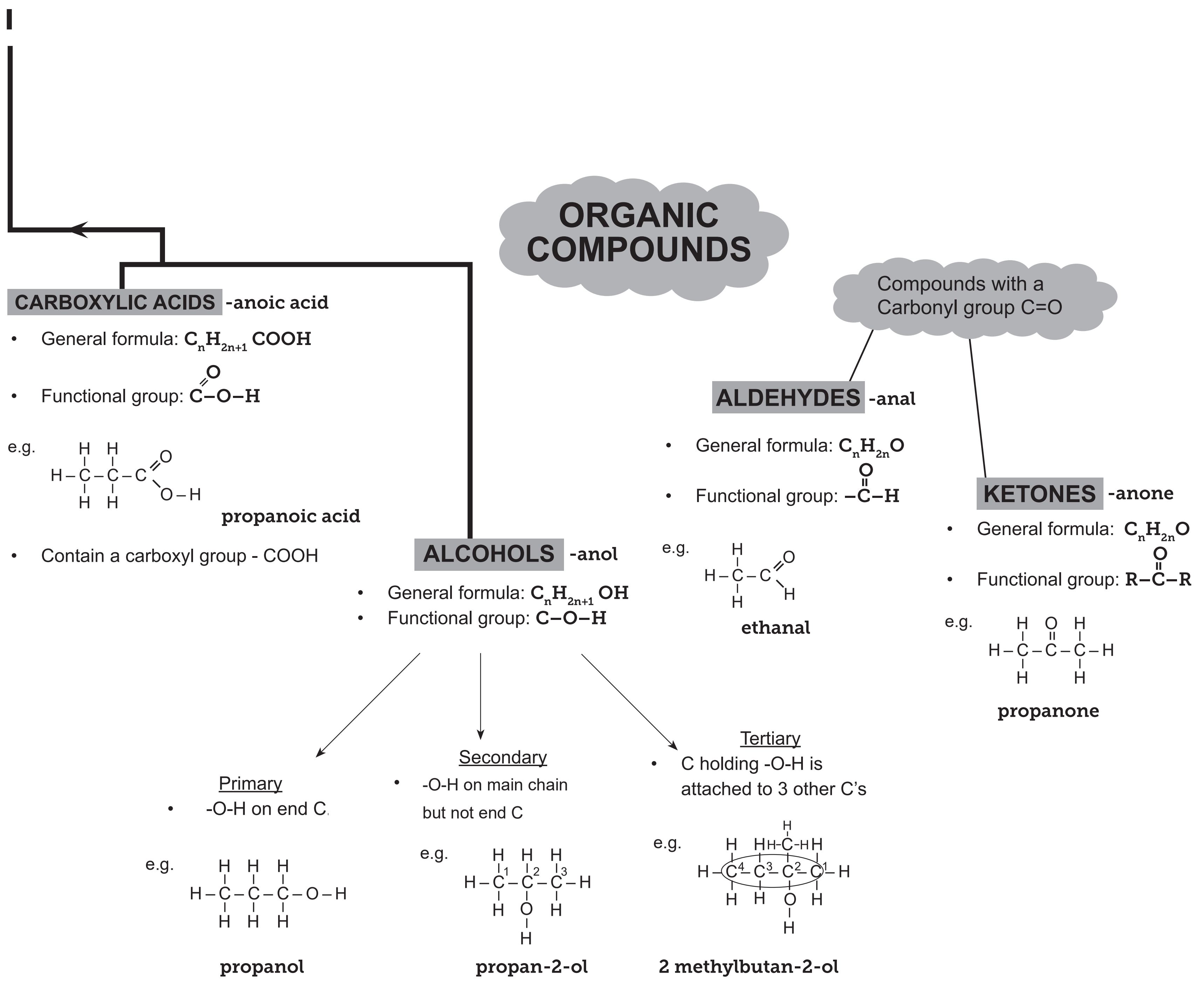
ethylpropanoate

ALKYL HALIDES

- Functional group: **C–X (X = Cl, Br, I)**

e.g.

1, 3–dichlorobutane



ORGANIC COMPOUNDS

CARBOXYLIC ACIDS **-anoic acid**

- General formula: $C_nH_{2n+1}COOH$
- Functional group: $\overset{O}{\overset{\|}{C}}-O-H$

e.g.

propanoic acid

- Contain a carboxyl group - COOH

ALCOHOLS **-anol**

- General formula: $C_nH_{2n+1}OH$
- Functional group: $C-O-H$

Primary
- -O-H on end C.

e.g.

propanol

Secondary
- -O-H on main chain but not end C

e.g.

propan-2-ol

Tertiary
- C holding -O-H is attached to 3 other C's

e.g.

2 methylbutan-2-ol

Compounds with a Carbonyl group C=O

ALDEHYDES **-anal**

- General formula: $C_nH_{2n}O$
- Functional group: $-\overset{O}{\overset{\|}{C}}-H$

e.g.

ethanal

KETONES **-anone**

- General formula: $C_nH_{2n}O$
- Functional group: $R-\overset{O}{\overset{\|}{C}}-R$

e.g.

propanone