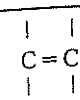
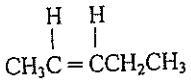
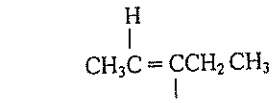
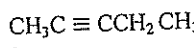
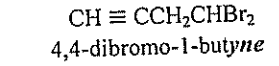
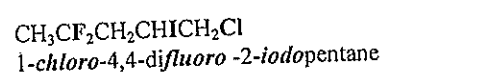
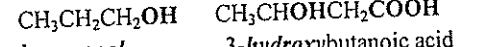
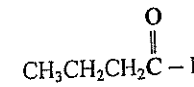
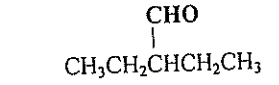
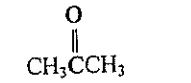
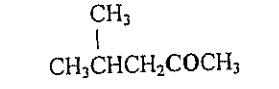
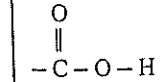
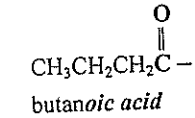
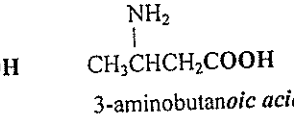
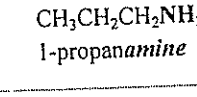
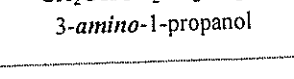
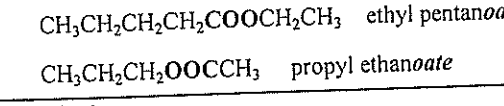
3. Functional groups

- **Functional groups** are atoms or groups of atoms that give an organic molecule its particular characteristics. (See Table 3.)
- The nomenclature of organic compounds with these functional groups follows the same rules as those previously outlined for hydrocarbons.
- If two or more functional groups occur in the same molecule then the **order of priority** for the **principal functional group** (highest to lowest) is carboxylic acid (–COOH), aldehyde (–CHO), ketone (–COC–), alcohol (–OH), amine ($–NH_2$), alkene (–C=C–), alkyne (–C≡C–), halogen (F–, Cl–, Br–, I–) and alkyl group (methyl, ethyl etc).

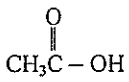
Table 3 Structure and nomenclature of common functional groups

Structural formula	Simplified formula	Class of compound	Prefix or suffix to stem	Example
	–CHCH–	alkene	**–ene**	 *cis*-2-pent***ene***  *trans*-2-pent***ene***
	–CC–	alkyne	**–yne**	 2-pent***yne***  4,4-dibromo-1-but***yne***
		haloalkane	**fluoro–** **chloro–** **bromo–** **iodo–**	 1-***chloro***-4,4-di***fluoro*** -2-***iodo***pentane
	–OH	alcohol	**–ol** or * **hydroxy–**	 1-propan***ol*** 3-***hydroxy***butanoic acid
	–CHO	aldehyde	**–al**	 butan***al***  2-ethylbutan***al***
	–CO–	ketone	**–one**	 propan***one***  4-methyl-2-pentan***one***
	–COOH	carboxylic acid	**–oic acid**	 butan***oic acid***  3-aminobutan***oic acid***
	–NH_2	amine	**–amine** or * **amino–**	 1-propan***amine***  3-***amino***-1-propanol
	–COO–	ester	**–oate**	 ethyl pentan***oate*** propyl ethan***oate***

* The optional prefix is usually used if a suffix of higher priority is already present in the name.

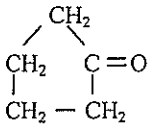
Set 14 Organic nomenclature

1. Name the **functional group** in each of the following organic structures.

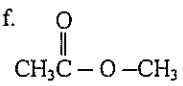
a. 

b. $CH_3CH_2CH_2Cl$

c. CH_3CH_2OH

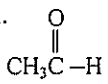
d. 

e. $NH_2CH_2CH_3$

f. 

g. $CH_2CHCH_2CH_3$

h. $CH_3CH(CH_3)CH_3$

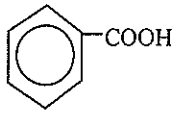
i. 

j. CH_3CH_2CHO

k. $CH_3COCH_2CH_3$

l. $CH_3CCCH_2CH_3$

m. CH_3COOCH_3

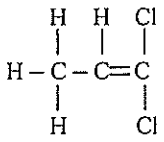
n. 

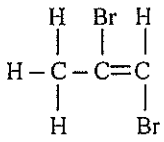
o. CH_3CH_2Br

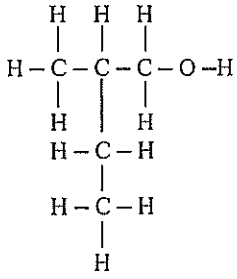
2. Draw suitable **structural formula** for the following organic compounds.

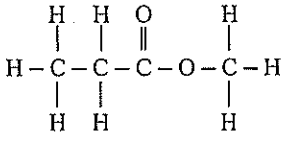
a. 2,2-dimethylpentane
b. butanone (or 2-butanone)
c. propyl ethanoate
d. 2-butanol
e. 3-methylbutanoic acid
f. 3-methyl-1-butanol
g. cyclohexanone
h. *cis*-2,3-dichloro-2-pentene
i. 3,3,3-tribromopropanoic acid
j. 2,4-diethylhexanal
k. 1-bromo-3-ethylcyclopentene
l. 3-ethylcyclohexanone
m. 1,1,1-trichloro-4-methyl-2-pentyne
n. ethyl methanoate
o. *trans*-1,2-diaminoethene
p. 3-amino-2-ethylpentanoic acid
q. 3,4-diiodobenzoic acid
r. 3-ethyl-2-methylheptanal
s. 1-chloro-3,5-diethylcyclohexene
t. *cis*-butendioic acid
u. 3,4-dibromo-3-ethyl-2-pentanol
v. ethyl propanoate
w. 2-hydroxybenzoic acid
x. butyl benzoate

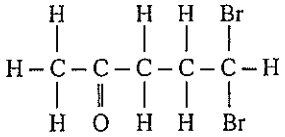
3. The **full structural formula** for several organic compounds are shown below. Give the **IUPAC name** for these substances.

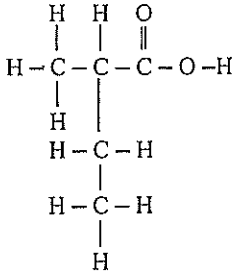
a. 

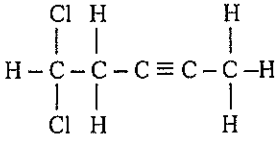
b. 

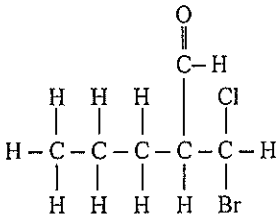
c. 

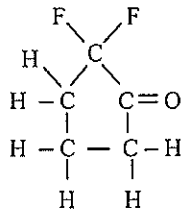
d. 

e. 

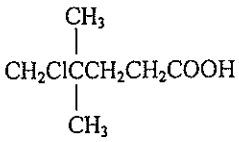
f. 

g. 

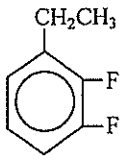
h. 

i. 

4. **Condensed structural formula** are shown here for some organic compounds. Give the **IUPAC name** for these substances. (It may be useful to write the full structural formula for these before attempting to name them.)

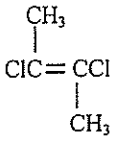
a. 

b. $CH_3CCCHCH_3CH_3$

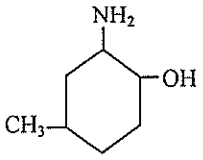
c. 

d. $HCOOCH_2CH_3$

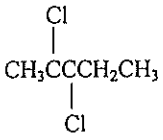
e. $CH_3CH_2CH_2COOCH_3$

f. 

g. $CH_3COCH_2CH_2CH_2CH_3$

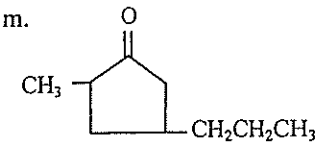
h. 

i. $CBr_3CHCH_3CHOHCH_3$

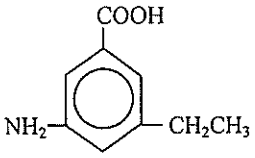
j. 

k. $HCCl_2CCCH_2CHCH_3CH_3$

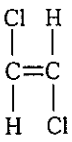
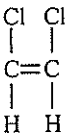
l. $CH_3(CH_2)_6COOH$

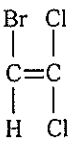
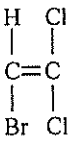
m. 

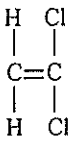
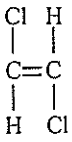
n. CH_3CHCH_3CHO

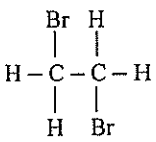
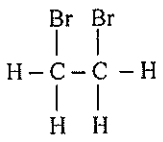
o. 

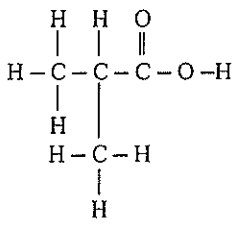
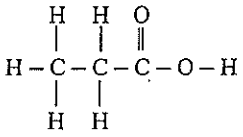
5. Examine the following pairs of compounds. Determine those pairs of compounds which represent:
   i. the **same compound**
   ii. **structural** isomers
   iii. **geometric isomers**, ie *cis-trans* isomers
   iv. different compounds that are **not isomers**.

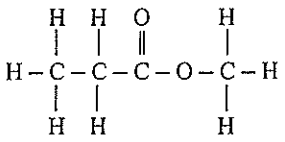
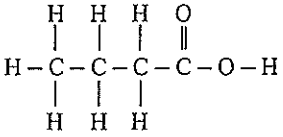
a.  *and* 

b.  *and* 

c.  *and* 

d.  *and* 

e.  *and* 

f.  *and* 

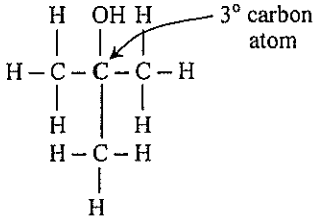
g. $CH_3COOCH_2CH_2CH_3$ *and* $CH_3CH_2COOCH_2CH_3$

h. 2-pentene *and* cyclopentane

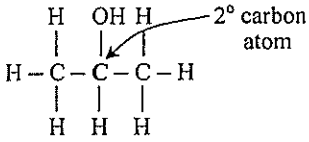
i. propanone *and* propanal

Classification of **primary**, **secondary** and **tertiary** alcohols is based upon the nature of the **carbon atom** to which the **–OH** functional group is attached.

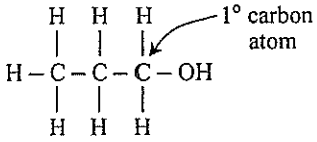
3° (tertiary) alcohol



2° (secondary) alcohol



1° (primary) alcohol



A **3° carbon** is one bonded to three other carbon atoms. A **2° carbon** is bonded to two other carbon atoms. A **1° carbon** is bonded to a single carbon atom.

6. **Name** the compounds described below.
   a. The straight chain alkene of formula C_4H_8 that does not have geometric isomers.
   b. The tertiary alcohol (see margin note) of molecular formula $C_4H_{10}O$.
   c. The two esters of molecular formula $C_3H_6O_2$.
   d. Two saturated hydrocarbons of molecular formula C_4H_8.
   e. An aldehyde and a ketone of molecular formula C_3H_6O.
   f. The aromatic compound with molecular formula C_7H_8.

7. **Name** the eight isomers of $C_5H_{12}O$ that contain an **alcohol** functional group. **Classify** these as **1°**, **2°** or **3°** alcohols.

8. A student named several organic compounds as indicated below. Unfortunately, although each name specifies a correct structure, the name given does not correctly follow the IUPAC system of nomenclature. Use the given name to determine the structure and hence give the **correct IUPAC name** for each compound.
   a. 4-hydroxy-1-pentanamine
   b. 2,2,2-trimethylethanoic acid
   c. 3-propylpentanal
   d. 1,1,1-trichloro-4-butanoic acid
   e. 1-methyl-1,3,5-cyclohexatriene
   f. trans-2,3-dibromopropane

11. The increase in mass occurring at electrode B is due to the reduction of copper: $Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$

$n(Cu) = \frac{m}{M} = \frac{0.972}{63.55} = 1.53 \times 10^{-2}$ mol Cu *and* $n(e^-) = 2 \times n(Cu) = 3.06 \times 10^{-2}$ mol

The increase in mass at electrode D is due to the formation of $X(s)$: $X(CN)_2^-(aq) + e^- \rightarrow X(s) + 2CN^-(aq)$

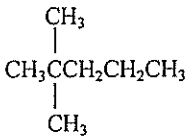
Also, the moles of electrons consumed at electrode B (3.06×10^{-2} mol) is the same as that consumed at electrode D.

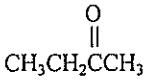
$n(X) = \frac{1}{1} n(e^-) = 3.06 \times 10^{-2}$ mol *and* $M(X) = \frac{m}{n} = \frac{6.05}{3.06 \times 10^{-2}} = 198$ g mol^{-1} (3 SF)

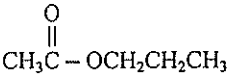
The metal has a molar mass of **198 g** (3 SF) and is most probably **gold** (molar mass 197).

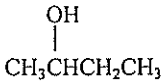
Unit 7 Set 14 Organic nomenclature

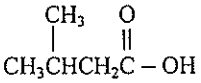
1. a. carboxylic acid; b. chloro; c. alcohol; d. ketone; e. amine or amino; f. ester; g. alkene; h. methyl; i. aldehyde; j. aldehyde; k. ketone; l. alkyne; m. ester; n. carboxylic acid; o. bromo

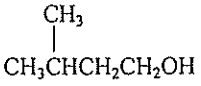
2. a. 

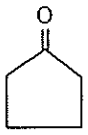
b. 

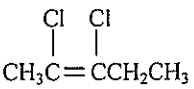
c. 

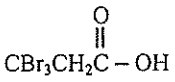
d. 

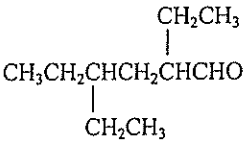
e. 

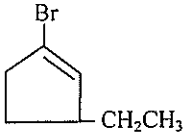
f. 

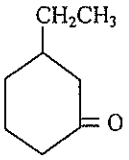
g. 

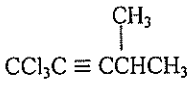
h. 

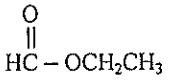
i. 

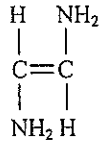
j. 

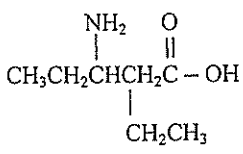
k. 

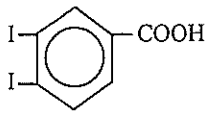
l. 

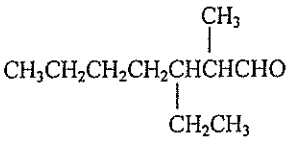
m. 

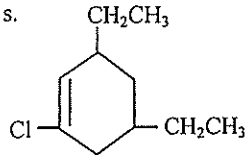
n. 

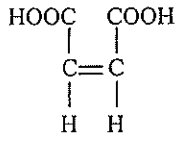
o. 

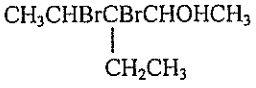
p. 

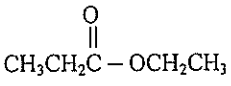
q. 

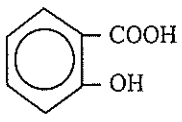
r. 

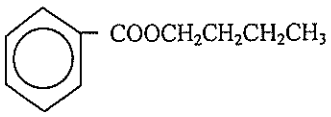
s. 

t. 

u. 

v. 

w. 

x. 

3. a. 1,1-dichloro-1-propene
b. *trans*-1,2-dibromo-1-propene
c. 2-methyl-1-butanol
d. methyl propanoate
e. 5,5-dibromo-2-pentanone
f. 2-methylbutanoic acid
g. 5,5-dichloro-2-pentyne
h. 3-bromo-3-chloro-2-propylpropanal
i. 2,2-difluorocyclopentanone

4. a. 5-chloro-4,4-dimethylpentanoic acid
   b. 4-methyl-2-pentyne
   c. 3-ethyl-1,2-difluorobenzene
   d. ethyl methanoate
   e. methyl butanoate
   f. *trans*-2,3-dichloro-2-butene
   g. 2-hexanone
   h. 2-amino-4-methyl-1-cyclohexanol
   i. 4,4,4-tribromo-3-methyl-2-butanol
   j. *cis*-2,3-dichloro-2-pentene
   k. 1,1-dichloro-5-methyl-2-hexyne
   l. octanoic acid
   m. 2-methyl-4-propylcyclopentanone
   n. 2-methylpropanal
   o. 3-amino-5-ethylbenzoic acid

5. a. geometric isomers
   b. same compound
   c. structural isomers
   d. same compound (C–C bond rotates)
   e. not isomers
   f. structural isomers
   g. structural isomers
   h. structural isomers
   i. structural isomers

6. a. 1-butene
   b. 2-methyl-2-propanol
   c. methyl ethanoate and ethyl methanoate
   d. cyclobutane and methylcyclopropane
   e. propanone and propanal
   f. methylbenzene (toluene)

7. 1° alcohols: 1-pentanol, 2-methyl-1-butanol, 3-methyl-1-butanol, 2,2-dimethyl-1-propanol
   2° alcohols: 2-pentanol, 3-pentanol, 3-methyl-2-butanol
   3° alcohols: 2-methyl-2-butanol

8. a. 5-amino-2-pentanol
   b. 2,2-dimethylpropanoic acid
   c. 3-ethylhexanal
   d. 4,4,4-trichlorobutanoic acid
   e. methylbenzene (toluene)
   f. 1,2-dibromopropane

Unit 8 Set 15 Reactions of hydrocarbons

1. a. $2C_4H_{10}(l) + 13O_2(g) \rightarrow 8CO_2(g) + 10H_2O(g)$
   b. $CH_3(CH_2)_5CH=CH_2(l) + HCl(g) \rightarrow CH_3(CH_2)_5CHClCH_3(l)$ The product must be 2-chlorooctane.
   c. $CH_3(CH_2)_4CH_3(l) + Br_2(aq) \rightarrow CH_3(CH_2)_4CH_2Br(l) + HBr(aq)$
   d. $2C_2H_2(g) + 5O_2(g) \rightarrow 4CO_2(g) + 2H_2O(g)$
   e. $CH_2=CH_2(g) + Br_2(aq) \rightarrow CH_2BrCH_2Br(l)$
   f. $CH_3CH_3(g) + 6Br_2(g) \rightarrow CBr_3CBr_3(l) + 6HBr(g)$
   g. $C_6H_6(l) + Br_2(aq) \rightarrow C_6H_5Br(l) + HBr(aq)$
   h. $2C_8H_{18}(l) + 17O_2(g) \rightarrow 16CO(g) + 18H_2O(g)$
   i. $CH\equiv CH(g) + 2H_2(g) \rightarrow CH_3CH_3(g)$
   j. $CH_3C\equiv CH(g) + HI(g) \rightarrow CH_3CI=CH_2(l)$ The product must be 2-iodopropene.
   k. $C_5H_8(l) + Br_2(aq) \rightarrow C_5H_8Br_2(l)$ The product must be 1,2-dibromocyclopentane.
   l. $CH_3CH_2CH_3(g) + 8Cl_2(g) \rightarrow CCl_3CCl_2CCl_3(s) + 8HCl(g)$
   m. $CH_3(CH_2)_2C\equiv CH(l) + HI(g) \rightarrow CH_3(CH_2)_2CI_2CH_3(l)$ The product must be 2,2-diiodopentane.

2. a. i. combustion ii. CO_2 and H_2O iii. The gas burns producing heat and light.
   b. i. substitution ii. chlorooctane and HCl iii. The chlorine water slowly changes from pale yellow-green to colourless.
   c. i. addition ii. 1,2-dibromocyclobutane iii. The bromine solution quickly changes from red-brown to colourless.
   d. i. substitution ii. chlorobenzene and HCl iii. The chlorine water slowly changes from pale yellow-green to colourless.
   e. i. addition ii. 1,1,2,2-tetrabromohexane iii. The bromine solution quickly changes from red-brown to colourless.

3. a. Yes. Propene will rapidly decolourise bromine water (red-brown to colourless). Propane does this much more slowly.
   b. No. An addition reaction occurs in both cases so they both rapidly decolourise bromine water.
   c. No. An addition reaction occurs in both cases so they both rapidly decolourise bromine water.
   d. Yes. An addition reaction occurs with cyclohexene rapidly decolourising bromine water (red-brown to colourless). Benzene decolourises bromine water much more slowly (substitution).
   e. No. A substitution reaction occurs in both cases so they both slowly decolourise bromine water.
   f. Yes. Cyclohexene undergoes addition (rapidly decolourises bromine), while cyclohexane undergoes substitution (slowly decolourises bromine water).