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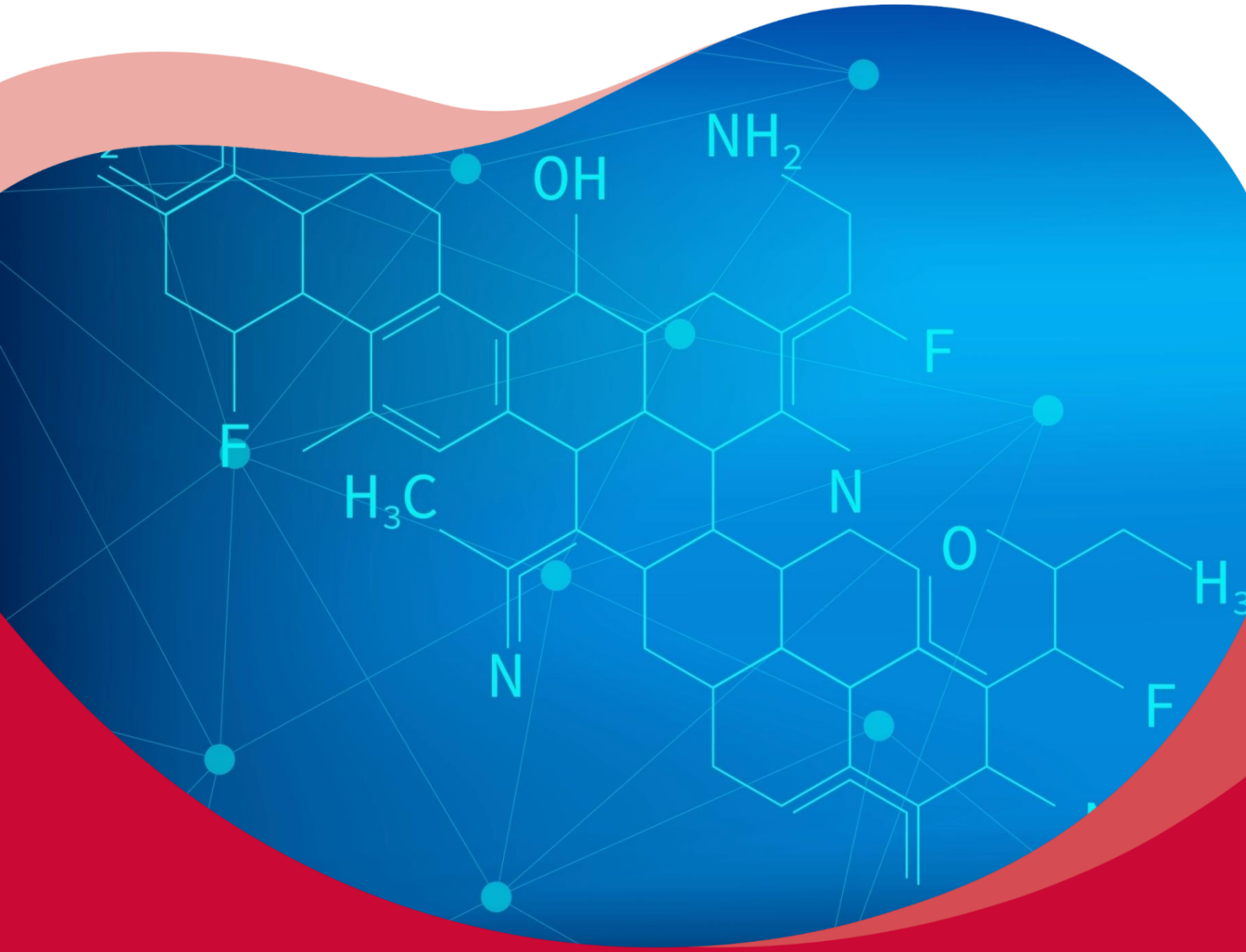

Chemical Nomenclature for use in Matriculation Examinations

2022

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Table of Contents

List of Tables

Foreword

This document is intended as a guide for teachers, examiners, students preparing for the Advanced (mainly), and Intermediate Matriculation Examinations in Chemistry of the University of Malta. It deals with the nomenclature of those inorganic and organic compounds likely to be relevant to the syllabus matter of these examinations.

The statements in this document must not be construed as extending, in any way, the examinable material described in the Syllabus for Intermediate and Advanced Chemistry of the Matriculation and Secondary Education Certificate Examinations Board.

The Syllabus Panel working on the review of the Advanced and Intermediate Chemistry Syllabus for 2021-2023 has approved this document.

May 2021

CHEMICAL NOMENCLATURE FOR USE IN MATRICULATION EXAMINATIONS

1. Chemical nomenclature in Matriculation examination papers

In setting examination questions for Matriculation Chemistry, the systematic names are derived from the rules of nomenclature as outlined in this publication.

In answers to examination questions, candidates may use any name or symbol, which is generally accepted for a compound or a group, unless the question is specifically on some aspect of nomenclature that falls within the syllabus.

Note that parts of the organic and inorganic rules of nomenclature discussed are not applicable for Intermediate Chemistry.

2. Inorganic Nomenclature

This section describes briefly some aspects of nomenclature as it pertains to those inorganic compounds as may be encountered in the syllabus material for Matriculation Chemistry.

2.1 Binary compounds

Binary compounds have names ending in '-ide' with the more electropositive element named first, e.g. ZnO is zinc oxide, OF_2 is oxygen difluoride. Hydroxides and cyanides break this rule even though they are not classified as binary compounds. Other exceptions are water, ammonia, methane, silane, and phosphine.

A roman numeral in parentheses after the name of an element indicates the oxidation state of that element in the compound and this is written for elements with a variable oxidation state. The above rules are exemplified in Table 1.

Table 1: Inorganic binary compounds

Formula	Systematic name
Cu_2O	copper(I) oxide
PCl_5	phosphorus(V) chloride
SO_2	sulfur(IV) oxide
NaCl	sodium chloride

Notice the spelling 'sulfur' for the element S (rather than 'sulphur') and this accords with IUPAC rules, although phosphorus retains its traditional spelling. Ag^+, the oxidation state may be omitted (even though a few silver (II) compounds exist since these will almost certainly not be encountered in the Matriculation syllabus).

2.2 Oxoacids and their salts

The names of oxoacids and their salts end in '-ic acid' and '-ate' respectively, giving the oxidation number of the central atom while the number of oxygen atoms need not be indicated as exemplified by Table 2 below. As an exception, the ion $S_2O_3^{2-}$ will be named 'thiosulfate' without reference to oxidation numbers.

Table 2: Examples of oxoacids and their salts

Formula	Systematic Name
HNO_3	nitric(V) acid
NO_3^-	nitrate(V) ion
HNO_2	nitric(III) acid
NO_2^-	nitrate(III) ion
H_2SO_4	sulfuric(VI) acid
SO_4^{2-}	sulfate(VI) ion
H_2SO_3	sulfuric(IV) acid
SO_3^{2-}	sulfate(IV) ion
HClO	chloric(I) acid
ClO^-	chlorate(I) ion
$HClO_3$	chloric(V) acid
ClO_3^-	chlorate(V) ion
$HClO_4$	chloric(VII) acid
ClO_4^-	chlorate(VII) ion
CrO_4^{2-}	chromate(VI) ion
MnO_4^-	manganate(VII) ion
H_3PO_4	phosphoric(V) acid
PO_4^{3-}	phosphate(V)
H_3PO_3	phosphoric(III) acid
PO_3^{3-}	phosphate(III)

2.3 Simple salts

Systematic names of simple salts include the name of the cation followed by the oxidation number, where applicable, followed by the name of the anion and its oxidation number, if applicable. Systematic names of simple salts are exemplified in Table 3.

Table 3: Systematic names of simple salts

Formula	Systematic name
$Al(NO_3)_3$	aluminium nitrate(V)
$KHCO_3$	potassium hydrogencarbonate
$CuSO_4$	copper(II) sulfate(VI)
$PbCO_3$	lead(II) carbonate

2.4 Double salts, basic salts and double (mixed) oxides

In double salts there are two cations that are independent of each other, though each might be hydrated, e.g. the alums; less commonly there may be more than one anion. The order of naming is that cations precede anions and within each category, the ions are listed in alphabetical order of their names.

In writing chemical formulae, however, the sequence within each class should be in alphabetical order of the symbols except that hydrogen is always cited last, before the anion. Basic salts are named as double salts with oxide or hydroxide anions whenever the structure is known and the same procedure is used for double (mixed) oxides. This is exemplified in Table 4 below.

Table 4: Systematic names of double salts, basic salts and double (mixed) oxides

Formula	Systematic name
$AlK(SO_4)_2.12H_2O$	aluminium potassium sulfate(VI)-12-water
$CrNH_4(SO_4)_2.12H_2O$	ammonium chromium(III) sulfate(VI)-12-water
$SOCl_2$	sulfur(IV) dichloride oxide
$NaHSO_3$	sodium hydrogensulfate(IV)
Pb_3O_4	lead(II,IV) oxide
Fe_3O_4	iron(II,III) oxide
CrO_2Cl_2	chromium(VI) dichloride dioxide

2.5 Coordination compounds

Coordination compounds are treated as consisting of a central metal atom or ion to which ligands (ions or molecules) are attached to form a complex.

As in simple ionic salts, for ionic coordination compounds, the cation is named first and then the anion. The name of the complex is formed by placing the names of the ligands in alphabetical order, ignoring numerical prefixes, before the name of the central species. The oxidation number of the central species is placed after the metal name for a complex cation and after the metal name and the suffix '-ate' for a complex anion. For some metals, the Latin version of the name is used in anionic complexes, the more important cases being ferrate for Fe, argentate for Ag, stannate for Sn and plumbate for Pb. There is no hyphen between the numerical prefixes and the names of the ligands (e.g. between 'hexa' and 'ammine' or 'aqua').
The prefixes bis-, tris- etc. are used if the name of the ligand includes a prefix such as di-, tri- etc.

Anionic ligands have names ending in 'o' derived by adding the letter to the stem name of the group, e.g. chloro for Cl^-, cyano for CN^-, OH^- hydroxo. For neutral ligands, the name of the free molecule is used as such but special names are given to some common ligands, of which the more important are aqua (H_2O), ammine (NH_3), carbonyl (CO) and nitrosyl (NO).

For the purposes of the Matriculation Examination, in writing formulae of complexes containing more than one type of ligand, the metal ion should always appear first but the ligands may be shown in any order. This is exemplified in Table 5 below.

Table 5: Systematic naming of coordination compounds

Formula	Systematic name
$[Cu(NH_3)_4]^{2+}$	tetraamminecopper(II)
$Ni(CO)_4$	tetracarbonylnickel(0)
$[Fe(CN)_5(NO)]^{2-}$	pentacyanonitrosylferrate(II)
$[Co(NH_3)_4(NO_2)Cl]NO_3$	tetraamminechloronitrocobalt(III) nitrate(V)
$[Mn(C_2O_4)_3]^{4-}$	tris(ethanedioato)manganate(II)
$LiAlH_4$	Lithium tetrahydridoaluminate

Use of the systematic name for ethylenediaminetetraacetic acid, which is 1,2-bis[bis(carboxymethyl)amino]ethane is not recommended and will not be tested; rather this compound should be referred to as "H_4edta" since "edta" is the commonly used term for the ligand formed from the parent acid by loss of protons. Similarly, use of the abbreviation "en" for ethane-1,2-diamine in formulae showing this substance reacting as a ligand is acceptable.

2.6 Hydrates

The number of water molecules of hydration are shown by a number after the name of the anhydrous substance as shown by this example: copper(II) sulfate(VI)-5-water. The formula is thus: $CuSO_4.5H_2O$.

When the extent of hydration is unknown, or the context warrants it, the word “hydrated” may be placed before the name of the anhydrous material.

2.7 List of recommended names of commonly used inorganic species

The following Table 6, shows the recommended names of the listed chemical species and other accepted names (where applicable).

Table 6: Recommended and other accepted names of listed chemical species

Formula	Recommended name	Also accepted as:
AlO_2^- or $Al(OH)_4^-$	aluminate ion	
NH_3 (aq)	aqueous ammonia	
$Ca(OH)_2$ (aq)	aqueous calcium hydroxide	limewater
C	carbon	Allotropes: diamond, graphite, fullerene
O_3	trioxygen (in discussing allotropy)	ozone
O_2	dioxygen (in discussing allotropy)	oxygen
H_3O^+	oxonium	hydroxonium

3. Organic Nomenclature

3.1 General Principles

The IUPAC nomenclature is used: every name consists of a root, one suffix and as many prefixes as necessary. For the purposes of the Matriculation Chemistry, the root is an aliphatic hydrocarbon or a single ring homocyclic system: multicyclic and heterocyclic compounds are not in the syllabi.

Compounds are regarded as derived from hydrocarbons by replacement of hydrogen atoms by alkyl or other groups and by introduction or saturation of multiple bonds. The systematic name is formed by attaching a suffix and prefixes to denote this substitution of hydrogen. While only one suffix may be used, as many prefixes as are needed may be included. The following list, Table 7, of functional groups defines the priority order for the principal group to be chosen as the suffix: the group nearest the top of the list has the higher priority.

Table 7: The priority order for the principal functional group to be chosen as the suffix. (limited to aromatic compounds.)*

Formula	Name as Suffix	Name as Prefix
RCOOH	alkan**oic acid**	
$RCOO^-$	alkan**oate ion**	
φSO_3H	benzene**sulfonic acid***	
$(RCO)_2O$	alkan**oic anhydride**	
RCOOR’	**alkyl** alkan**oate**	
RCOCl	alkan**oyl chloride**	
$RCONH_2$	alkan**amide**	
RCN	alkane**nitrile**	cyano
RCHO	alkan**al**	oxo
R_2CO	alkan**one**	oxo
ROH	alkan**ol**	hydroxy
RNH_2	alkan**amine**	amino

In the carbon-containing functional groups given in the list, the carbon atom of the functional group is counted in the carbon chain, which forms the root. Any other group present in a structure, including those not in the above list is named by a prefix (Table 8).

For certain structures, it may be required to include carbon-containing functional groups in the name of the compound by using a prefix (e.g. “chlorocarbonyl” for -COCl). Questions involving the naming of such structural formulae will not be set in the Matriculation Examination except for the cyano and oxo groups for aliphatic compounds.

Table 8: Groups that are always named as a prefix.

Formula	Name as Prefix
–Br	bromo
–Cl	chloro
–F	fluoro
–I	iodo
–OR	alkoxy
$–NO_2$	nitro

If more than one prefix is needed, they are placed in alphabetical order. Multiplying prefixes, such as di- or tri- do not affect alphabetical order.

The syllables 'ane', 'ene' and 'yne' for denoting alkane, alkene and alkyne functionality respectively are regarded to form part of the root and not as suffixes. When 'ene' and 'yne' appear together in a name, they are included in alphabetical order. For the endings 'ene' and 'yne' lower locants are assigned first to the endings as a set without regard to the type. In the event of a tie between the two, the alkene takes priority. When other functional groups are present in the molecule the priority of carbon-carbon multiple bonds is considered to be lower than that of amines. This is exemplified in Table 9 below.

Table 9: Examples of organic molecules with carbon-carbon multiple bonds

Compound	Systematic Name
$HC{\equiv}CCH{=}CHCH_3$	pent-3-en-1-yne
$HC{\equiv}CCH_2CH{=}CH_2$	pent-1-en-4-yne
$CH_2{=}CHCH_2CH_2NH_2$	but-3-en-1-amine
$CH_3CH{=}CHCH_2OH$	but-2-en-1-ol

The carbon atoms in the parent hydrocarbon (the root) are numbered consecutively and the appropriate number (locant) precedes the name of the prefix or suffix indicating the group attached to that carbon atom. The numbering is arranged to give, *first*, the lowest possible number to the group cited by a suffix *and then* the lowest possible individual numbers (not sum!) to those groups cited as prefixes, observing that when series of locants containing the same number of terms are compared term by term, that series is "lowest" which contains the lowest number on the occasion of the first difference. This principle is applied irrespective of the nature of the substituents as exemplified in Table 11.

An italicised atomic symbol is used in appropriate circumstances to indicate the atom to which the substituent is attached, for example, *N*-ethylbutanamide.

Locants should be omitted when the structure can be deduced without them, especially the locant '1', for example, butanone not butan-2-one, but if the locants are included, this will not be deemed as constituting a penalty.

Amines will be named as the alkanamine. Quaternary ammonium salts should be named as alkyl substituted ammonium salts as exemplified in Table 10 below.

Table 10: Systematic naming for quaternary ammonium salts

Compound	Systematic Name
$(CH_3)_4NCl$	tetramethylammonium chloride
$CH_3CH_2N(CH_3)_3Br$	ethyltrimethylammonium bromide

The following list, Table 11, which is not comprehensive, is intended to illustrate further the application of the rules of nomenclature for aliphatic compounds as described in this section.

Table 11: A non-comprehensive list illustrating the application of the rules of nomenclature for aliphatic compounds

Compound	Systematic Name
$CH_3CH_2CH(CH_3)CH(CH_3)(CH_2)_4CH(CH_3)_2$	2,7,8-trimethyldecane
$CH_3CH=CHCH(CH_3)_2$	4-methylpent-2-ene
$HC\equiv C\text{-}CH_2CH=CHCH_3$	hex-4-ene-1-yne
$CH_2ICH_2CHBrCHClCH_3$	3-bromo-4-chloro-1-iodopentane
$CH_3CHClCH_2CH(CH_3)_2$	2-chloro-4-methylpentane
$HOCH_2CH_2NH_2$	2-aminoethanol
$CH_2(OH)CH_2OH$	ethane-1,2-diol
$CH_3OC(CH_3)_3$	2-methoxy-2-methylpropane
$HOCH_2CH_2CH_2CHO$	4-hydroxybutanal
$CH_3CH(OH)CN$	2-hydroxypropanenitrile
CH_3COCH_2COOH	3-oxobutanoic acid
CCl_3COOH	trichloroethanoic acid
$CH_3COOCH(CH_3)_2$	2-propyl ethanoate
$CH_3CH(CH_3)CH_2CONHCH_2CH_3$	*N*-ethyl-3-methylbutanamide
$CH_3CH(NH_2)CH_3$	propan-2-amine
$(CH3)_3NH$	dimethylmethanamine
$CH_3CH(NHCH_3)CH_2CH_2CH_3$	*N*-methylpentan-2-amine
$CH_2(NH_2)CH_2NH_2$	ethane-1,2-diamine
$CH_3CH\equiv C^-$	propynide ion

3.2 Aromatic compounds

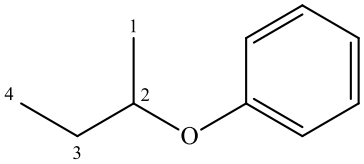
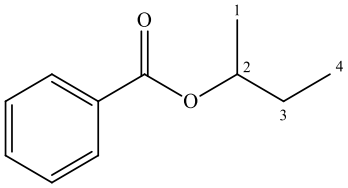
Benzene, C_6H_6, is the simplest aromatic molecule and may be represented as a Kekulé structure or a hexagon/circle symbol.

Homologues of benzene are named as alkylbenzenes e.g. ethylbenzene for $C_6H_5CH_2CH_3$, 2-pentylbenzene for $C_6H_5CH(CH_3)CH_2CH_2CH_3$.

For alkyl groups where one or more hydrogens are replaced with halogens, brackets are used to show that the halogen is part of the alkyl group and not bonded to the ring e.g. (chloromethyl)benzene for $C_6H_5CH_2Cl$.

If a functional group is directly bonded to the ring, then the name of the molecule depends on whether the group is referred to with a prefix or suffix. Acid groups, acid derivative groups, and the aldehyde group use a suffix. Groups like halogens, nitro, and alkoxy use a prefix. This is exemplified in Table 12 below:

Table 12: A non-comprehensive list illustrating the application of the rules of nomenclature for aromatic compounds

Compound	Systematic Name
$C_6H_5NO_2$	nitrobenzene
C_6H_5Cl	chlorobenzene
$C_6H_5OCH_2CH_3$	ethoxybenzene
$C_6H_5O(CH_3)CH_2CH_3$	prop-2-oxybenzene
$C_6H_5OC_6H_5$	phenoxybenzene
C_6H_5COOH	benzoic acid
$C_6H_5SO_3H$	benzenesulfonic acid
C_6H_5COCl	benzoyl chloride
$C_6H_5CONH_2$	benzamide
$C_6H_5CONH(CH_3)$	*N*-methylbenzamide
C_6H_5CN	benzonitrile
$C_6H_5COOCH_2CH_3$	ethyl benzoate
$C_6H_5COO(CH_3)CHCH_2CH_3$	2-butyl benzoate
$C_6H_5COOC_6H_5$.	phenyl benzoate
C_6H_5CHO	benzaldehyde
	but-2-oxybenzene
	2-butyl benzoate

When the substituent directly bonded to benzene is a hydroxyl group, then the molecule is called phenol, C_6H_5OH (not hydroxybenzene).

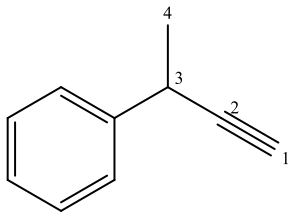
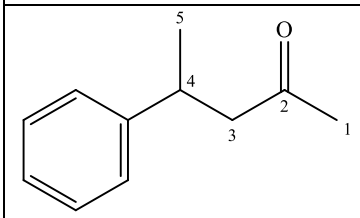
Benzene with an amino group bonded to it, $C_6H_5NH_2$, will be referred to as benzenamine.

If more than one of the same functional group is present, then a prefix di-, tri- and so on will be used in front of the prefix/suffix representing that group together with numbers to indicate the relative positions e.g. 1,2-dichlorobenzene, 1,3-dinitrobenzene, benzene-1,4-diol (not phenol for polyhydroxy-compounds only), benzene-1,2-dioic acid.

Students are expected to be familiar with the nomenclature for disubstituted benzene rings which in place of numeral locants uses the prefixes *ortho-, meta-* and *para-* (abbreviated *o-, m-, p-*) e.g. *p*-nitrophenol for 4-nitrophenol; or *o*-dichlorobenzene for 1,2-dichlorobenzene.

When a side-chain contains a functional group (the functional group is not directly bonded to the ring) it would be possible either to name the compound as a derivative of benzene or to name it as a phenyl-substituted aliphatic compound. The guiding principle is to use a name that places emphasis on the functional group that dominates the chemistry being taught at school level. Thus, while $C_6H_5CH{=}CH_2$ can either be named ethenylbenzene or phenylethene, at Advanced Matriculation Level, the latter name will be used as the substance is studied as a substituted alkene. This is exemplified in Table 13 below:

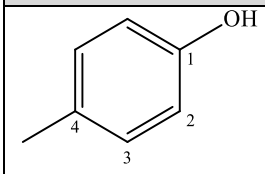
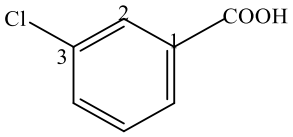
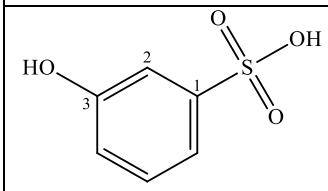
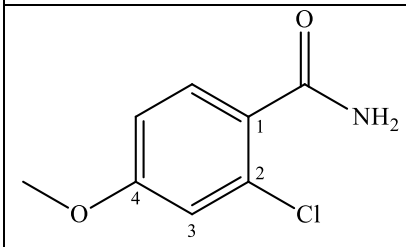
Table 13: Systematic naming of substituted aromatic compounds.

Compound	Systematic Name
$C_6H_5CH_2CH_2CH_2OH$	3-phenylpropan-1-ol
$C_6H_5COCH_3$	phenylethanone
$C_6H_5CH(CH_3)C{\equiv}CH$	3-phenylbut-1-yne
$C_6H_5CH_2CH_2CH_2COCl$	4-phenylbutanoyl chloride
	3-phenylbut-1-yne
	4-phenylpentan-2-one

When more than one type of functional group is bonded to the ring, the molecule is named according to the principal group on the ring whilst the other group is named with a prefix as given in the list of priority groups in Table 7 of the General Principles section.

The benzene ring is numbered from the carbon atom to which the principal group is attached. Table 14 below exemplifies the naming of the aromatic compounds with more than one substituent on the benzene ring.

Table 14: Systematic naming of the aromatic compounds with more than one substituent on the benzene ring.

Compound	Systematic Name
	4-methylphenol
	3-chlorobenzoic acid
	3-hydroxybenzenesulfonic acid
	2-chloro-4-methoxybenzamide

The following list, which is not comprehensive, is intended to illustrate further the application of the rules of nomenclature for aromatic compounds as described in this section.

Table 15: A non-comprehensive list, to illustrate further the application of the rules of nomenclature for aromatic compounds.

Systematic Name	
arenes	2-amino-3-phenylpropanoic acid
aryl	2-methyl-1,3,5-trinitrobenzene
benzaldehyde oxime	*N*-methylbenzenamine
benzenediazonium ion	4-nitrobenzenamine
chloro-2-methylbenzene	4-(phenylazo)phenol
(trichloromethyl)benzene	phenylmethanol
1-bromo-2-chloro-4-nitrobenzene	phenylmethanamine
2-methylbenzoic acid	diphenylmethanone
2,4,6-tribromophenol	sodium phenoxide
benzene-1,3-diamine	3-phenylpropanal

3.3 Terms and generic names

The following list contains some of the terms and generic names which continue to be useful and may be encountered in examination questions.

Acetal; acetylide; alcohol; aldehyde; aliphatic; alkoxide; alkyl; amide; amine; amino acid; anhydride; aromatic; aryl; carbohydrate; carbonyl; carboxyl; ester; ether; hemiacetal; ketone; monosaccharide; nitrile; peptide; phenol; polymer; polysaccharide; protein; sugar; sulfonic acid.

The terms 'primary, secondary, tertiary' as applied to classes of alcohols, halogenoalkanes, and amines remain useful; however, prefixes such as n-, iso-, sec-, tert- etc will not be used. Thus iso-propyl becomes 2-propyl.

3.4 Polymers

Polymers are named according to one of two systems: either one that is based on the source (monomer) or process from which the polymer is made or one based on the structure of the polymer itself. Most addition polymers are named according to the monomer or source from which they were formed while most condensation polymers are described by the types of linkages involved in their structures.

It is recommended to use the source-based system of naming for addition polymers.

The source-based naming of addition polymers leads to poly(alkene) descriptions, e.g. poly(ethene), poly(propene), poly(chloroethene), poly(phenylethene), poly(tetrafluoroethene).

Names for condensation polymers are difficult to construct and will not be tested. These polymers should be described by simple block diagrams such as:

…–NHCO-⌇-CONH-X-NHCO-⌇-CONH-X-NHCO-…

The latter structure could represent a polyamide such as, e.g., Nylon-6,6 derived from condensation of a six-carbon diamine (hexane-1,6-diamine) and a six-carbon diacid chloride (hexanedioyl chloride).

3.5 Policy on dual naming

Traditional names are not examinable. Only the names listed in this booklet are examinable.

Optical activity in molecules will be represented by the symbols + (dextrorotatory) and – (laevorotatory). The use of the letters *d* and *l* will be discontinued.