

# Unit title: Organic Chemistry

Unit code: **R/601/0352**

QCF level: **4**

Credit value: **15**

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## Aim

This unit develops the principles and practical techniques of organic chemistry. Rationalisation of structure and bonding is used to aid understanding of reaction mechanisms and functional group conversions.

## Unit abstract

This unit provides a comprehensive coverage of the principles of organic chemistry. These principles are used to develop aspects of structure, bonding and isomerism together with organic reaction mechanisms and functional group chemistry. Experimental methods fundamental to organic chemistry are also covered. The unit content is appropriate for employees working in chemical industry, for learners hoping to gain such employment or for learners progressing to higher levels of study.

## Learning outcomes

### On successful completion of this unit a learner will:

- 1 Understand the structure and bonding of organic compounds
- 2 Understand organic reaction mechanisms
- 3 Understand the reactions of hydrocarbons
- 4 Understand the reactions of mono-functional group compounds.

## Unit content

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### 1 Understand the structure and bonding of organic compounds

*The structures of organic molecules:* alkanes; alkenes; alkynes; methods of representation; display/structural formula; condensed formula; skeletal/line formula; stereochemical 'flying wedge' formula; bond angles; bond lengths; shapes

*Bonding in organic molecules:*  $sp^3$ ,  $sp^2$ ,  $sp$  hybridisation;  $\sigma$  and  $\pi$  bonds

*Classification of organic molecules:* alkanes; alkenes; alkynes; alcohols; ethers, aldehydes; ketones; carboxylic acids; esters; acid anhydrides; acid halides; amines; amides, cyanides (nitriles); haloalkanes; cyclic alkanes/alkenes and difference to arenes; substituted arenes limited to haloarenes and phenol

*Isomerism in organic molecules:* structural isomerism; chain, positional, function group; stereoisomerism; geometric including cis/trans notation; optical isomerism including effect on plane polarised light

*Physical properties of organic molecules:* boiling/melting points in relation to intermolecular forces of dispersion, dipole-dipole, hydrogen bonding; effect of branching on boiling/melting points; solubility and insolubility in water

*Experimental methods:* distillation; fractional distillation; recrystallisation; column chromatography; use of melting points and thin layer chromatography (TLC); structure identification to include infrared spectroscopy e.g. identification of alcohols, carboxylic acids, carbonyl compounds; mass spectroscopy; high resolution nuclear magnetic resonance

### 2 Understand organic reaction mechanisms

*Categorise:* recognise and categorise reagents with justification (electrophiles, nucleophiles, radicals, acids, bases)

*Types of reactions:* recognise and categorise reactions with justification (addition, substitution, elimination, rearrangement, condensation)

*Reaction profile diagrams:* energy profiles; reaction coordinate; transition state; reaction intermediate; activation energy; catalysis

*Mechanisms:* use of curly arrows, one and two-electron movements; homolysis; heterolysis; free radical chlorination of methane; nucleophilic substitution ( $SN_1$  and  $SN_2$ ) reactions of haloalkanes; elimination reactions ( $E_1$  and  $E_2$ ) of haloalkanes; nucleophilic addition reactions of aldehydes and ketones; electrophilic addition reactions of alkenes including application of Markovnikov's rule

### 3 Understand the reactions of hydrocarbons

*Alkanes*: sources; halogenation; combustion; free radical substitution reactions; uses as fuels and sources of industrial materials

*Alkenes*: electrophilic addition of hydrogen halides; Markovnikov addition; explanation of Markovnikov in terms of carbocation stability; rearrangements of carbocations; addition of halogens including in the presence of water; addition of water in the presence of acids; reaction with peroxydicarboxylic acids; reaction with potassium manganate (VII); reaction with ozone; reduction with hydrogen; polymerisation

*Alkynes*: hydration; hydrogenation, Lindlar catalyst and use of sodium in liquid ammonia

### 4 Understand the reactions of mono-functional group compounds

*Haloalkanes*: nucleophilic substitution reactions with  $\text{H}_2\text{O}$ ,  $\text{OH}^-$ ,  $\text{CN}^-$ ,  $\text{NH}_3$ ,  $\text{RO}^-$ ,  $\text{SN}_1$  and  $\text{SN}_2$ ; stereochemical consequences; elimination reactions;  $\text{E}_1$  and  $\text{E}_2$  reactions; elimination vs substitution; Grignard reagent formation; Grignard reactions with aldehydes, ketones; use of haloalkanes to synthesise other functional group compounds

*Alcohols and phenols*: acidity; reaction with sodium; reaction with hydrogen halides and phosphorus halides; oxidation; dehydration; halogenation of phenols; use of alcohols to synthesise other functional group compounds

*Carbonyl compounds*: aldehydes and ketones; oxidation and reduction; nucleophilic addition reactions, water, ammonia, hydrogen cyanide; haloform reaction; condensation with ammonia derivatives including the importance of 2,4 dinitrophenylhydrazine; reaction with Grignard reagents; use of aldehydes and ketones to synthesise other functional group compounds; carboxylic acids; acid/base reactions; esterification; acid halides; acid anhydrides; use of carboxylic acids to synthesise other functional group compounds

*Amines and amides*: acid/base reactions; amide formation; diazotisation; coupling of diazonium compounds; use of amines and amides to synthesise other functional group compounds

*Experimental work*: preparation of pure samples of selected functional group compounds and polymers

## Learning outcomes and assessment criteria

<b>Learning outcomes</b> On successful completion of this unit a learner will:	<b>Assessment criteria for pass</b> The learner can:
LO1 Understand the structure and bonding of organic compounds	1.1 illustrate the structures of organic molecules 1.2 explain bonding in organic molecules 1.3 categorise organic molecules by functional group 1.4 discuss isomerism in organic structures 1.5 explain physical properties of organic molecules 1.6 safely use experimental methods to purify and identify organic compounds
LO2 Understand organic reaction mechanisms	2.1 justify molecules or ions as nucleophiles, electrophiles, radicals, acids, bases 2.2 justify reactions as addition, substitution, elimination, rearrangement or condensation 2.3 explain terms associated with reaction profile diagrams 2.4 justify specified organic reactions using mechanisms to show electron movements
LO3 Understand the reactions of hydrocarbons	3.1 explain the reactions of alkanes, alkenes and alkynes in terms of reaction mechanisms
LO4 Understand the reactions of mono-functional group compounds	4.1 explain the reactions of haloalkanes, alcohols, carbonyl compounds and amines/amides in a functional group conversion context 4.2 justify substitution and elimination reactions as either unimolecular or bimolecular 4.3 undertake safely experimental organic reactions to produce selected compounds

## Guidance

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### Links

This unit has particular links with the following units within this qualification:

- Unit reference number R/601/0349: *Inorganic Chemistry*
- Unit reference number Y/601/0353: *Physical Chemistry*
- Unit reference number A/601/0362: *Organic Chemistry of Aromatic and Carbonyl Compounds*
- Unit reference number F/601/0217: *Biochemistry of Macromolecules and Metabolic Pathways*.

### Essential requirements

#### Delivery

Delivery must integrate theoretical considerations with practical outcomes. The industrial importance of reactions and processes must be emphasised. Some of the concepts learnt in *Unit R/601/0349: Inorganic Chemistry* should be applied in this unit to the structure and shapes of organic molecules. This can be achieved by use of molecular modelling software packages and physical models of organic molecules, particularly for showing differences in structural and stereoisomerism.

#### Assessment

Assessment of learning outcome 1 must clearly demonstrate the relationship between structure and bonding and the physical properties of organic molecules and their potential to exist in isomeric forms. The types of compounds used to illustrate these aspects should be representative of those used to develop learning outcomes 3 and 4.

For learning outcome 2, assessment must confirm learners' understanding of reagent types and reaction types and the susceptibility of specific functional groups to attack by specific classes of reagents. Learners must show confidence in the use of curly arrows to represent both one and two electron movements to demonstrate reaction mechanisms across a range of organic reaction types.

In learning outcome 4, assessment emphasis should be on synthesis and interconversion of functional groups, integrated and reinforced by reaction mechanisms showing electron movements. Throughout the unit, where appropriate, practical work should be integrated with understanding theoretical principles.

#### Resources

Learners will need access to advanced laboratory facilities with appropriate technical support.

The Royal Society of Chemistry website has a large range of resources from *The Molecular World* series of CD ROMs including: Molecular Modelling and Bonding; Alkenes and Aromatics; Separation, Purification and Identification; Chemical Kinetics and Mechanism; Mechanism and Synthesis.

### **Employer engagement and vocational contexts**

Many aspects of the content for learning outcomes 3 and 4 can be delivered in an industrial context. Universities often allow visits to their departments and such visits may be useful for exploring experimental methods, especially spectroscopic equipment.