**BTEC Level 3 Nationals in Applied Science**

**Additional Guidance**

**Unit 5 – Section A – Properties and uses of substances**

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| **Essential Content** | **Additional Guidance** |
| **A1 Relating properties to uses and production of substances** | **Learners should:** |
| * Understand the chemical properties of substances:
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| * amphoteric character of alumina
 | * know that alumina is aluminium oxide
* know the formula (Al2O3)
* understand the term amphoteric (the ability to act as an acid or as a base), and in comparison to acids and bases
* understand the chemical properties of alumina (ie amphoteric nature)
* be able to construct and balance equations to show acid-base nature of aluminium oxide
 |
| * basic character of metal oxides and hydroxides
 | * be able to write balanced chemical and ionic equations for the reaction of metal oxides or metal hydroxides with acids to include:
	+ group 1, 2 and period 4 transition metal oxides and hydroxides
	+ with common inorganic acids (hydrochloric acid, sulfuric acid, nitric acid)
* understand how equations show basic behaviour
 |
| * ease of electrolysis
 | * understand the terms electrolysis, electrolyte, cathode and anode
* know the conditions (molten or in solution) under which electrolysis takes place and associated energy requirements
* know that electrolysis conditions will be more demanding as the reactivity of the metal increases
* know that it is an energetically more feasible option than reduction of a metal oxide
* be able to predict products of electrolysis under given conditions
* be able to write half equations for reduction and oxidation
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| * Understand the uses of substances:
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| * Ca(OH)2 in acidic effluent treatment
 | * understand how calcium hydroxide neutralises acid
* be able to write balanced chemical and ionic equations for the reaction
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| * transition metals, transition metal oxides and transition metal complexes as catalysts
* vanadium (V) oxide as catalyst in the contact process, iron as a catalyst in the Haber process
 | * understand the term transition metal (an element which can form one or more ions with an incomplete d subshell)
* understand the key physical and chemical characteristics
	+ incomplete d subshell
	+ coloured compounds
	+ variable oxidation states
	+ catalysis
	+ complex ion formation
* understand the term complex ion (central metal atom or ion surrounded by ligands and bonded with dative covalent bonds)
* understand associated characteristics of complex ions including:
	+ ligands (molecules or ions with lone pairs of electrons that can be donated to form a dative covalent bond)
	+ dative covalent (co-ordinate) bond
* be able to draw structural formulae of complex ions
* know the term catalyst (substance which speeds up a reaction and is unchanged at the end of the reaction)
* understand how catalysts function in terms of:
	+ effect on energy requirements and activation energy
	+ different mechanisms, including redox and adsorption
	+ different phases, including homogeneous and heterogeneous
* understand how catalyst efficiency can be improved and inhibited
* know details of the Contact process and the Haber process
* understand the use of vanadium(V) oxide and iron / iron oxides as catalysts in the Contact and Haber processes respectively
* be able to apply concepts of catalysis to other industrial and medical contexts
 |
| * alumina in refractories
 | * understand the chemical and physical properties of alumina as an ionic compound (melting and boiling point, thermal and electrical conductivity)
 |
| * Understand purification, extraction and manufacture of:
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| * alumina from bauxite
 | * understand the processes and chemistry involved in the purification, extraction and manufacture of alumina from bauxite using the Bayer process
* understand the reasons for the use of the operating conditions in the process
* be able to write equations for the processes involved
 |
| * titanium from its ore
 | * understand the processes and chemistry involved in the purification, extraction and manufacture of titanium from its ores (including rutile, ilmenite) using the Kroll process
* understand the reasons for the use of the operating conditions in the process
* be able to write equations for the processes involved
 |
| * aluminium from alumina, Hall–Héroult
 | * understand the processes and chemistry involved in the purification, extraction and manufacture of aluminium using the Hall-Héroult process
* understand the reasons for the use of the operating conditions in the process
* be able to write equations for the processes involved
 |
| * electrolysis of brine to produce sodium hydroxide, hydrogen and chlorine, diaphragm cell and membrane cell
 | * understand the processes involved in the purification, extraction, manufacture and uses of sodium hydroxide, hydrogen and chlorine obtained by the electrolysis of brine
* understand the reasons for the use of the operating conditions in the process, including the use of the diaphragm cell, the membrane cell and no barrier dividing the cell
* be able to write equations for the processes involved
 |
| * Understand how to relate the properties of substances to their production and uses:
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| * comparison of production methods in relation to properties
 | * be able to compare production methods, to include:
	+ electrolysis against reduction of a metal oxide
	+ electrolysis of a concentrated solution against a molten compound
	+ changes in conditions of pressure and concentration (high against low) and surface area of solid reactants or catalysts (large against small)
	+ the use of a catalyst against the absence of a catalyst
	+ batch processes against continuous processes
 |
| * + choice of a substance for use in relation to its properties
 | * understand the choice of a substance for a use in relation to its properties, to include:
	+ alumina and other metal oxides
	+ aluminium
	+ calcium hydroxide and other metal hydroxides
	+ titanium, other transition metals and their compounds
	+ hydrogen, chlorine and sodium hydroxide
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| **A2 Structures, reactions and properties of commercially important organic compounds** |  |
| Understand the following: |  |
| * straight-chain, branched and cyclic alkanes and alkenes, including isomers
 | * understand that alkanes and alkenes are hydrocarbons
* understand differences between alkanes and alkenes as saturated and unsaturated compounds
* understand differences between straight-chain, branched and cyclic compounds
* understand and recognise structural isomerism
* understand and recognise geometric stereoisomerism (E / Z; cis / trans)
 |
| * general formulae of alkanes and alkenes
 | * know and be able to use general formulae CnH2n+2 (for alkanes) and CnH2n (for alkenes) to determine molecular formulae
 |
| * International Union of Pure and Applied Chemistry (IUPAC) nomenclature
 | * be able to apply IUPAC rules to name organic molecules from their formulae, and determine formulae from IUPAC names, to include:
	+ straight-chain, branched and cyclic structures (no more than 6 carbon atoms in the longest chain)
	+ geometric isomers
	+ alkanes
	+ alkenes
	+ alcohols
	+ halogenoalkanes
 |
| * structure representations, full (displayed) structural formulae showing all the bonds, shortened structural formulae
 | * be able to draw structural formulae from the molecular formulae of organic molecules and vice versa
 |
| * 3D representations using wedge/dashed line diagrams, skeletal formulae
 | * be able to convert molecular and structural formulae into and from 3D representations
* be able to recognise and use wedges and dashed lines to show bonds (forward and backwards)
* be able to recognise and use skeletal formulae (no hydrogen atoms)
 |
| * symmetric and asymmetric alkenes
 | * be able to identify alkenes as being symmetrical or asymmetrical with respect to the groups/atoms on the double bond
* be able to recognise the implications for expected products from the reactions of symmetrical or asymmetrical alkenes
 |
| * sigma and pi-bonding in alkanes and alkenes
 | * understand that sigma (σ) bonds in alkanes and alkenes arise from the head-on overlap of s, p or hybrid orbitals
* understand that pi (π) bonds in alkenes arise from the sideways overlap of p orbitals and have two lobes above and below the carbon atoms
* be able to recognise and draw representations of sigma (σ) and pi (π) bonds
* know that alkanes only have sigma (σ) bonds and alkenes have sigma (σ) and pi (π) bonds
 |
| * hybridisation
 | * understand that atomic orbitals (such as s and p) can combine to form a new hybrid orbital with a different shape, energy and geometry, in preparation for covalent bonding
* understand that a carbon atom can undergo hybridisation when:
	+ one s and three p orbitals combine to produce four sp3 orbitals which give rise to four sigma bonds at 109.5o bond angles (tetrahedral shapes) as in alkanes
	+ one s and two p orbitals produce three sp2 orbitals which give rise to three sigma bonds at 120o bond angles (trigonal planar shapes) as in ethene and benzene
	+ one s and one p orbital produce two sp orbitals which give rise to two sigma bonds at 180o bond angles (linear shapes) as in carbon dioxide
* understand that each hybrid orbital that is formed is the same shape, energy and geometry, and is occupied by a single electron which is available for sharing in a covalent bond
* understand that any p orbitals that are not hybridised can overlap sideways to form pi bonds
 |
| * bond angles, lengths and strengths in alkanes, alkenes, benzene
 | * understand simple electron pair repulsion theory in relation to hydrocarbons
* know bond angles associated with 4 bonding electron pairs (109.5o), 3 bonding electron pairs (120o) and 2 bonding electron pairs (180o) around a central carbon atom
* understand that as the number of bonds between carbon-carbon atoms increases the bond length decreases and the bond strength increases
* understand that the bond length between carbon atoms decreases from alkane to benzene to alkene, whilst bond strength increases
* know that a sigma bond is stronger than a pi bond due to greater orbital overlap, but that sigma and pi bonds together are stronger than either a sigma or pi bond alone
* understand and be able to represent the structure of a benzene ring (all six carbon atoms arranged in a hexagon, each carbon with sigma bonds to two other carbons and hydrogen, and a pi system above and below the ring of carbon atoms).
 |
| * increase in boiling point with chain length and intermolecular forces of attraction
 | * understand that the boiling point increases for alkanes and alkenes with increasing chain length
* understand that isomers with branching have lower boiling points
* understand the effects on boiling point in terms of strength of intermolecular forces of attraction
* understand that the strength of intermolecular forces depends upon size of molecule / numbers of electrons / surface area
 |
| * mechanisms of hydrocarbon reactions
 | * understand the mechanisms of hydrocarbon reactions to include:
	+ free radical substitution
	+ electrophilic addition
	+ free radical addition
	+ homolytic bond fission
	+ heterolytic bond fission
* be able to use curly arrows to show movement of electrons and formation of covalent bonds
* understand and be able to draw stepwise processes
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| * free radical substitution in alkanes
 | * understand free radical substitution in alkanes to include:
	+ initiation
	+ propagation
	+ termination
	+ the use of uv light or high temperature as conditions
	+ halogens (chlorine and bromine)
	+ different alkanes
* understand and be able to draw mechanism stages (single-headed curly arrows are not required)
* be able to name and draw products
 |
| * electrophilic addition of water, halogens, hydrogen halides and sulfuric acid in alkenes
 | * be able to write equations, name and draw products from electrophilic addition of alkenes (to include symmetric and asymmetric alkenes)
* understand and be able to draw mechanism stages
* be able to assign dipoles and use double-head curly arrows to show heterolytic bond fission or covalent bond formation
 |
| * stability of carbocations
 | * understand that a carbocation is formed during electrophilic addition mechanisms
* be able to predict and draw the structure(s) of carbocations from symmetric and asymmetric alkenes
* understand stability of carbocations in terms of the electron donating effect of alkyl branches
* understand why one product is favoured over another, using the structure of a carbocation
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| * reactions of commercial importance:
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| * use of free radical polymerisation of alkenes and hydration of ethene
 | * understand and represent the mechanism of free radical addition polymerisation for simple alkenes
* be able to recognise and draw polymers to include poly(ethene), poly(propene), poly(styrene), poly(chloroethene) (PVC), poly(tetrafluoroethene) (PTFE)
* understand the properties and uses of poly(ethene), poly(propene), poly(styrene), PVC, PTFE

be able to write equations and mechanisms for the hydration of ethene |
| * cracking of hydrocarbons
 | * know the conditions required to crack hydrocarbons
* understand that smaller chain alkanes and alkenes are produced
* understand the purpose of cracking and the uses of the products
* be able write equations and predict products
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| * combustion of alkanes
 | * be able to predict products of complete and incomplete combustion of alkanes
* be able to write chemical equations for the combustion of alkanes
* understand the importance of combustion
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| **A3 Energy changes in industry** |  |
| * Know the Kelvin scale of temperature
 | * be able to convert temperature from degrees Celsius into Kelvin and vice-versa
* understand the term absolute zero, where temperature 0.00K = - 273.15oC
 |
| * Know the definition of enthalpy change, ∆*H* = ∆*U* + *p*∆*V*, also called ‘change in heat content’
 | * be able to define the equation for enthalpy change (∆H)
* know and apply the equation relating enthalpy change to internal energy change (∆U), pressure (p) and change in volume (∆*V*)
 |
| * Know the standard conditions:
 |  |
| * 1 × 105 Pa (100 kPa)
 | * know standard conditions of pressure, temperature and concentration
 |
| * 298 K
 |
| * per mole (mol-1).
 |
| * Understand enthalpy change under standard conditions, ∆*H*o
 | * know that the standard symbol indicates that standard conditions have been used
* understand why it is important to state the conditions used in enthalpy change data
* be able to identify reactions, processes and situations that are not under standard conditions
* be able to comment upon the validity of enthalpy change data based upon the conditions
 |
| * Know the units of standard enthalpy change kJ mol-1
 | * know the standard units for standard enthalpy change
* be able to convert these to and from J or J mol-1 as required
 |
| * Understand the system and surroundings
 | * understand what is meant by system and surroundings
* be able to identify the system and surroundings for given situations (e.g. an acid and alkali reacting in a solution is the system, everything outside of this system is the surroundings)
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| * Understand the sign convention
 | * know that heat energy (enthalpy) transfer from the system to the surroundings is negative
* know that heat energy (enthalpy) transfer from the surroundings to the system is positive
 |
| * Understand exothermic and endothermic reactions and processes
 | * be able to recognise exothermic and endothermic reactions and processes
* know that the sign convention of enthalpy change is negative for exothermic changes, and positive for endothermic changes
* understand that the temperature of the surroundings will increase when the system undergoes an exothermic process and will decrease when a system undergoes an endothermic process
 |
| * Understand reaction profiles
 | * be able to draw and understand enthalpy reaction profile diagrams for exothermic and endothermic reactions
* be able to calculate activation energy and overall enthalpy changes from enthalpy reaction profile diagrams
* understand the effect of a catalyst upon the shape of an enthalpy reaction profile
 |
| * Know the definitions of a range of standard enthalpy changes related to reactions in A1 and A2:
 | The general symbol ∆*H*or will be used to represent the standard enthalpy change for a given reaction |
| * combustion
 | * be able to define the standard enthalpy change of combustion as the enthalpy change that occurs when one mole of a substance is burnt completely in oxygen under standard conditions
* know the symbol for the standard enthalpy change of combustion (∆*H*oc)
* be able to recognise combustion from a supplied equation
* be able to write a chemical equation representing the standard enthalpy change of combustion for a given substance
* understand complete combustion of a substance may not occur in practice for reasons such as:
	+ non-standard conditions
	+ limited supply of oxygen
	+ high activation energy
* know and understand why ∆*H*oc = 0 kJ mol-1 for oxygen
 |
| * formation
 | * be able to define the standard enthalpy change of formation as the enthalpy change that occurs when one mole of a substance is formed from its elements in their standard states under standard conditions
* know the symbol for the standard enthalpy change of formation (∆*H*of )
* be able to recognise formation from a supplied equation
* be able to write a chemical equation representing the standard enthalpy change of formation for a given substance
* understand formation of desired substance may not occur in practice, for reasons such as:
	+ non-standard conditions
	+ alternative products
	+ high activation energy
* know and understand why ∆*H*of = 0 kJ mol-1 for elements in their standard states
 |
| * hydration
 | Learners should: * be able to define the standard enthalpy change of hydration as the enthalpy change that occurs when one mole of gaseous ions is dissolved in water to make an infinitely dilute solution under standard conditions
* know the symbol for the standard enthalpy change of hydration (∆*H*ohyd )
* be able to recognise hydration from a supplied equation
* be able to write a chemical equation representing the standard enthalpy change of hydration for a given ion
* understand factors that influence the size of enthalpy change of hydration, to include:
	+ charge of the ion
	+ size of the ion
 |
| * + interpretation of the size and sign of values
 | * be able to comment upon the size and sign of different enthalpy changes
* be able to suggest whether a reaction is energetically feasible (i.e. likely to occur) or suitable for an intended purpose (e.g. as a fuel) from the size and sign of the enthalpy change
* understand the limitations of what can be deduced from the size and sign of an enthalpy change (i.e. how far or fast a reaction will occur)
* know that enthalpy changes of combustion and hydration are always exothermic
* know that enthalpy changes of formation may be exothermic or endothermic
 |
| * literature values.
 | * be able to compare enthalpy change data from experiments or calculations against literature values
* understand the reasons for differences, to include :
	+ non-standard conditions
	+ heat loss or gain
	+ incomplete or competing reactions
 |
| * Understand the measurement of enthalpy changes:
 |  |
| * specific heat capacity of water
 | * understand the term specific heat capacity as the energy required to raise the temperature of 1 kg of a substance by 1 K
* know that value for water is 4.18 kJ K-1 kg-1 (or J K-1 g-1)
 |
| * enthalpy change in water in contact with a reaction
 | * understand the principles of calorimetry (measurement of enthalpy change)
* know the equipment used in calorimetry
* know the measurements needed to determine the enthalpy change from a reaction where the heat energy is transferred to / from water,
* know that the temperature change is measured indirectly in these cases
* know the measurements needed to determine the enthalpy change for a reaction that occurs within water (i.e. in a solution)
* know that the temperature change is measured directly in these cases
 |
| * heat *Q* = *mc*∆*t*
 | * know that *m* = mass of water, *c* = specific heat capacity, and *∆T* = change in temperature
* be able to use the equation *Q = mc∆T* to calculate the heat transferred (Q) or other quantities in the equation
 |
| * Calculate enthalpy changes from supplied data
 | * be able to calculate enthalpy changes from supplied data, to include:
	+ ∆*H* = ∆*U* + *p*∆*V*
	+ ∆*H*or = Σ ∆*H*of (products) – Σ ∆*H*of (reactants)
	+ ∆*H*or = Σ ∆*H*oc (reactants) – Σ ∆*H*oc (products)
	+ *Q = mc∆T*
	+ the use of Hess energy cycles
 |