National Unit specification: general information

Unit title: Inorganic Chemistry (SCQF level 7)

Unit code: H1FJ 13

Course: Chemistry (Revised)

Superclass:	RD
Publication date:	April 2012
Source:	Scottish Qualifications Authority
Version:	01

Summary

This Unit develops a knowledge and understanding of Inorganic Chemistry within the contexts of electromagnetic radiation and atomic spectra, atomic orbitals and electronic configurations, valence shell electron pair repulsion theory (VSEPR) to predict molecular shape and transition metal chemistry. The Unit develops the candidate's knowledge and understanding of atomic theory, shapes of molecules and polyatomic ions as well as reasons why transition metal compounds are coloured and make such good catalysts in the manufacture of the many useful materials produced by the chemical industry. The Unit also seeks to develop the candidate's problem solving abilities and practical skills.

Outcomes

1 Demonstrate and apply knowledge and understanding related to *Inorganic Chemistry*.
2 Demonstrate skills of scientific experimentation and investigation within the context of *Inorganic Chemistry*.

Recommended entry

Entry for this Unit is at the discretion of the centre. However candidates would normally be expected to have attained the skills and knowledge required by the following or equivalent:

- Higher Chemistry (Revised)
- Higher Chemistry

General information (cont)

Unit title: Inorganic Chemistry (SCQF level 7)

Credit points and level

0.5 National Unit credit at SCQF level 7: (4 SCQF credit points at SCQF level 7*)

**SCQF credit points are used to allocate credit to qualifications in the Scottish Credit and Qualifications Framework (SCQF). Each qualification in the Framework is allocated a number of SCQF credit points at an SCQF level. There are 12 SCQF levels, ranging from Access 1 to Doctorates.*

Core Skills

Achievement of this Unit gives automatic certification of the following:

Complete Core Skill	None
Core Skill component	Critical Thinking at SCQF level 6 Using Graphical Information at SCQF level 6

There are also opportunities to develop aspects of Core Skills which are highlighted in the Support Notes of this Unit specification.

National Unit specification: statement of standards

Unit title: Inorganic Chemistry (SCQF level 7)

Acceptable performance in this Unit will be the satisfactory achievement of the standards set out in this part of the Unit specification. All sections of the statement of standards are mandatory and cannot be altered without reference to SQA.

Outcome 1

Demonstrate and apply knowledge and understanding related to *Inorganic Chemistry*.

Performance Criteria

(a) Make accurate statements about facts, concepts and relationships relating to *Inorganic Chemistry*.
(b) Use knowledge of *Inorganic Chemistry* to solve problems.
(c) Use knowledge of *Inorganic Chemistry* to explain observations and phenomena.

Outcome 2

Demonstrate skills of scientific experimentation and investigation in the context of *Inorganic Chemistry*.

Performance Criteria

(a) Use a range of data-handling skills in a scientific context.
(b) Use a range of skills related to the evaluation of scientific evidence.

Evidence Requirements for this Unit

Evidence is required to demonstrate that candidates have met the requirements of the Outcomes.

For each of the Unit Outcomes, written and/or recorded oral evidence of the appropriate level of achievement is required. This evidence must be produced under closed-book, supervised conditions within a time limit of 30 minutes.

The Instrument of Assessment must sample the content in each of the following areas:

- Electromagnetic radiation and atomic spectra
- Atomic orbitals and electronic configurations
- Shapes of molecules and polyatomic ions
- Transition metals

An appropriate Instrument of Assessment would be a closed-book, supervised test with a time limit of 30 minutes. Items in the test should cover all the Performance Criteria associated with both Outcomes 1 and 2, and could be set in familiar or unfamiliar contexts.

Further detail on the breadth and depth of content is provided within in the appendix to the specification.

National Unit specification: statement of standards (cont)

Unit title: Inorganic Chemistry (SCQF level 7)

For Outcome 2, PC (a) candidates are required to demonstrate that they can use a range of data-handling skills. These skills include selecting, processing and presenting information. Information can be presented in a number of formats including: chemical formulae, balanced chemical equations, diagrams showing molecular shape, diagrams depicting laboratory apparatus, line graphs, scatter graphs, tables, diagrams and text.

For Outcome 2, PC (b), candidates are required to demonstrate that they can use a range of skills associated with the evaluation of scientific evidence. These skills include drawing valid conclusions and making predictions.

The standard to be applied and the breadth of coverage are illustrated in the National Assessment Bank items available for this Unit. If a centre wishes to design its own assessments for this Unit they should be of a comparable standard.

National Unit specification: support notes

Unit title: Inorganic Chemistry (SCQF level 7)

This part of the Unit specification is offered as guidance. The support notes are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 20 hours.

Guidance on the content and context for this Unit

The recommended content together with suggestions for possible contexts and activities to support and enrich learning and teaching are detailed in the Course specification.

This Unit allows candidates to develop knowledge and understanding of Inorganic Chemistry within the contexts of electromagnetic radiation, atomic spectroscopy, shapes of atomic orbitals, electronic configurations, patterns in the Periodic Table, shapes of molecules and polyatomic ions and some chemistry of the transition metals including colour and catalysis. This Unit also seeks to develop the candidate’s problem solving abilities and practical skills.

This Unit offers a diverse and rich vein of contexts and opportunities for practical work as highlighted in the ‘Possible contexts and activities’ column of the content tables. Opportunities exist for candidates to learn as part of a group through practical work undertaken in partnership or in teams. By developing a greater understanding of some of the concepts in atomic structure candidates are better able to understand more about electronic configurations, shapes of molecules, colour in inorganic compounds and how transition metal compounds can act as catalysts in chemical reactions used to produce everyday household products.

Guidance on learning and teaching approaches for this Unit

General advice on approaches to learning and teaching is contained in the Course specification.

Guidance on approaches to assessment for this Unit

Outcomes 1 and 2

It is recommended that a holistic approach is taken for assessment of these Outcomes. Outcomes 1 and 2 can be assessed by an integrated end of Unit test with questions covering all the Performance Criteria. Within one question, assessment of knowledge and understanding and skills of experimentation and investigation can occur. Each question can address a number of assessment standards from either Outcome 1 or 2.

Appropriate assessment items are available from the National Assessment Bank.

Unit title: Inorganic Chemistry (SCQF level 7)

Opportunities for the use of e-assessment

E-assessment may be appropriate for some assessments in this Unit. By e-assessment we mean assessment which is supported by Information and Communication Technology (ICT), such as e-testing or the use of e-portfolios or social software. Centres which wish to use e-assessment must ensure that the national standard is applied to all candidate evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. Further advice is available in *SQA Guidelines on Online Assessment for Further Education (AA1641, March 2003), SQA Guidelines on e-assessment for Schools (BD2625, June 2005)*.

Opportunities for developing Core Skills

This Unit provides opportunities to develop *Communication, Numeracy, Information and Communication Technology (ICT)* and *Problem Solving* skills in addition to providing contexts and activities within which the skills associated with *Working with Others* can be developed.

Outcome 1, PC (b) and (c) develop a candidate's ability to communicate effectively key concepts and to explain clearly chemical phenomena in written media.

Within this Unit candidates will need to extract and process information presented in both tabular and graphical formats developing the Core Skill of *Numeracy*. Candidates will gain experience in a range of calculations building competence in number.

The appendix to this Unit specification contains an extensive list of 'Possible Contexts and Activities' which include a large number of web based activities, computer simulations and modelling opportunities which all serve to develop higher levels of competence in the key *ICT* skills including; Accessing Information and Providing/Creating Information.

The Unit appendix contains an extensive range of practical laboratory exercises which provide candidates with the opportunity to Work Co-operatively with Others.

Problem Solving skills are central to the sciences and are assessed through Outcome 1, PCs (b) and (c) and also through Outcome 2, PCs (a) and (b).

This Unit has the Using Graphical Information component of Numeracy, and the Critical Thinking component of Problem Solving, embedded in it. This means that when candidates achieve the Unit, their Core Skills profile will also be updated to show that they have achieved Using Graphical Information and Planning and Organising at SCQF level 6.

Disabled candidates and/or those with additional support needs

The additional support needs of individual candidates should be taken into account when planning learning experiences, selecting assessment instruments, or considering whether any reasonable adjustments may be required. Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**

History of changes to Unit

Version	Description of change	Date

Additional copies of this Unit specification can be purchased from the Scottish Qualifications Authority. Please contact the Business Development and Customer Support team, telephone 0303 333 0330.

The left hand column below details the content in which candidates should develop knowledge and understanding. The middle column contains notes, which give further details of the breadth and depth of content expected. The right-hand column gives possible contexts and activities which could be used to develop knowledge, understanding and skills. Further details on many of the activities mentioned in the final column can be obtained from **National Qualifications Online**, part of the Education Scotland online service. Where such online support exists the 💻 symbol appears in the text.

Inorganic Chemistry 20 hour Unit		
Content	**Notes**	**Possible contexts and activities**
1 Electromagnetic radiation and atomic spectra		
1(a) Electromagnetic waves	Electromagnetic radiation may be described in terms of waves and can be characterised in terms of wavelength and/or frequency. The relationship between these quantities is given by $c=f\lambda$ where c represents the speed of light, f represents the frequency of the wave (s^{-1}) and λ represents the wavelength (m). When radiation in the visible part of the electromagnetic spectrum is being described, it is common to specify wavelength in terms of nanometres (nm).	An internet search on ‘CD or DVD spectroscope’ will produce a plethora of sites with simple instructions which allow candidates to make individual spectroscopes from any unwanted CDs or CD-ROMs. 💻 An online and printable electromagnetic spectrum is available from the Royal Society of Chemistry 💻 c can be taken as $3{\cdot}00 \times 10^{8}$ m s^{-1} (See Data Booklet) Frequency is often quoted in Hz which is the same as s^{-1}.
1(b) Dual nature of radiation — waves and particles	When electromagnetic radiation is absorbed or emitted by matter, it appears to be behaving more like a stream of particles than as a wave. These particles are known as photons. When a photon is absorbed or emitted, energy is gained or lost by electrons within the substance. The photons in high frequency radiation can transfer greater amounts of energy than photons in low frequency radiation. The energy associated with a single photon is given by $E=hf$ where ‘h’ represents Planck’s constant. For Chemists, it is more convenient to express the energy associated with a mole of photons which is given by $E=Lhf$ giving the energy in J mol^{-1} where L represents Avogadro’s constant.	Video on the dual nature of light can be found on the internet 💻 $h = 6{\cdot}63 \times 10^{-34}$ J s (See Data Booklet) $L = 6{\cdot}02 \times 10^{23}$ mol^{-1} (See Data Booklet) To get E, in kJ mol^{-1}, it is more convenient to use $E = Lhf/1000$ or $E = Lhc/1000\lambda$. L is the number of formula units in one mole of the substance. (Formula units can be atoms, molecules or groups of ions depending on how the formula is usually written and on the type of bonding structure present).

Content	Notes	Possible contexts and activities
1(c) Atomic emission	When energy is transferred to atoms, electrons within the atoms may be promoted to higher energy levels. To allow the electrons to return to their original levels, energy must be lost from the atom. This energy is released in the form of a photon. The spectrum of light emitted (atomic emission spectrum) is not continuous, but consists of a series of lines at discrete frequencies. This phenomenon provides direct evidence for the existence of discrete (quantised) energy levels for electrons. An atom can be considered as emitting a photon of light energy when an electron moves from a higher energy level to a lower energy level. Each element produces a unique pattern of frequencies of radiation in its emission spectrum.	Candidates can observe atomic emission by carrying out flame tests. RSC website gives more information. 💻 Spectacular demonstration versions in which an alcohol spray is used to produce coloured flames over a metre long could also be used. Can be found on the RSC website and in the RSC publication 'Classic Chemistry Demonstrations' No. 34 page 80. 💻 To view an atomic emission spectrum, a simple spectroscope (such as the 'homemade' devices produced from unwanted CDs) can be used to view a vapour discharge lamp or, if good blackout conditions are available, from a flame test. Fluorescent tube lamps, commonly used for classroom lighting, contain mercury vapour. If a spectroscope is used to view an illuminated fluorescent lamp, a series of purple lines from the atomic emission spectrum of mercury can be observed. SSERC activity with filter paper soaked in brine to observe sodium spectrum. A useful resource on spectroscopy and the identification of elements from emission spectra can be found on the 800mainstreet.com website. 💻 A method of making a home-made spectroscope can also be found on the internet. 💻 SSERC are currently developing an instrument using a camera or phone with a diffraction grating attachment.

Content	Notes	Possible contexts and activities
1(d) Atomic spectroscopy	Atomic emission spectroscopy and atomic absorption spectroscopy are used to identify and quantify the elements present in a sample. In absorption spectroscopy, electromagnetic radiation is directed at an atomised sample. Radiation is absorbed as electrons are promoted to higher energy levels. An absorption spectrum can be produced by measuring how a sample's transmission of light varies with wavelength. In emission spectroscopy, high temperatures are used to excite the electrons within atoms. As the electrons drop to lower energy levels, photons are emitted. An emission spectrum can be produced by measuring how much light is emitted at different wavelengths. Each element produces a characteristic absorption/emission spectrum which can be used to identify that element. In atomic spectroscopy, the concentration of an element within a sample is related to the intensity of light emitted or transmitted.	Resources describing Atomic Absorption are available from the RSC. 💻 Interesting anecdotes can be provided of the forensic uses of Atomic Absorption Spectroscopy in such cases as the investigation of toxic levels of heavy metals in Isaac Newton's hair due to his alchemical pastimes and the high levels of lead in men’s hair treated with "Grecian" hair products. A free science video by ‘Brightstorm’ on atomic emission spectra is available 💻 Videos on use of spectroscopy in astronomy, on the spectrum of stars and on the absorption and emission spectra of hydrogen are also available. 💻 A very useful website from uoregon.edu has an applet which shows the absorption and emission spectra of most elements just by clicking on the appropriate element on a Periodic Table. 💻 Light from a sodium lamp passing through a sodium flame from, say, a sodium pencil produces a shadow when projected on to a white screen.

Content	Notes	Possible contexts and activities
2 Atomic orbitals and electronic configurations		
2(a) Atomic orbitals	The discrete lines observed in atomic emission spectra can be explained if electrons, like photons, display the properties of particles and waves. Within the atom, electrons behave as waves and there are different sizes and shapes of wave possible around the nucleus. These are known as orbitals and each can hold a maximum of two electrons. Any electron within an atom can be uniquely identified by a set of four quantum numbers. The principal quantum number, ***n***, specifies the energy of the electron and also indicates the average distance of the electron from the nucleus. ***n*** can take the values 1, 2, 3, …. and all electrons with the same value of ***n*** constitute an electron shell or energy level. The angular momentum quantum number, ***l***, specifies the shape of the orbital in which the electron is contained. ***l*** can take the values 0, 1, …., ***n***-1 and all electrons with the same value of ***l*** in a given shell constitute a subshell. It is often more convenient to use the letters *s*, *p*, *d*, … corresponding to ***l*** = 0, 1, 2, … respectively to label the subshells. The magnetic quantum number, ***m***, labels the orbitals within a subshell and indicates the orientation or direction of the orbital in which the electron is contained. The allowed values of ***m*** are –***l***,....0,… +***l***. The spin magnetic quantum number, ***s*** indicates the spin direction of an electron within an orbital and can have only two values: + ½ or –½. Candidates should be able to recognise *s*, *p* and *d* orbitals from their shapes and draw diagrams of *s* and *p* orbitals.	Electrons, in fact, behave as standing waves within the atom. Wave mechanics tells us that there are different shapes and sizes of standing waves possible around the nucleus, which are known as orbitals. The circumference of the standing wave is always equal to an integral number of wavelengths. The principal quantum number, *n*, is the circumference of the orbital in terms of the number of wavelengths. The RSC website has pages which offer very clear and attractive representations of orbitals with accompanying text which refers to the wave nature of the electron. A free science video by ‘Brightstorm’ covers quantum numbers but this is beyond the level required and would need some previous teaching or learning. 💻 A Sci-Comm video showing 3D models helping to visualise s, p and d orbitals is available 💻 The RSC website has an animation which can be used to illustrate the absorption and emission of light by an atom. It can also be run set at ‘Orbital Model’ and shows a pictorial representation of the orbitals and labels them using the "1s" "2p" type of nomenclature. 💻

Content	Notes	Possible contexts and activities
2(b) Electronic configurations of atoms in the ground state	Any atom can only have a maximum of two electrons within any single orbital. The aufbau principle states that electrons fill orbitals in order of increasing energy. The relative energies corresponding to each orbital can be represented diagrammatically for the first four shells of a multi-electron atom. In an isolated atom the orbitals within each subshell are degenerate. Hund's Rule states that when degenerate orbitals are available, electrons fill each singly, keeping their spins parallel before spin pairing starts. The Pauli exclusion principle states that no two electrons in the one atom can have the same set of four quantum numbers. Put more simply it states that no orbital can hold more than 2 electrons and the 2 electrons must have opposite spins. Electronic configurations using spectroscopic notation and orbital box notation can be written for elements of atomic numbers 1 to 36.	A free science video by 'Brightstorm' covers orbital box diagrams and covers the aufbau principle, Pauli exclusion principle and Hund's rule. 💻 Another free science video by 'Brightstorm' (brightstorm.com) covers electronic configurations💻 Teachers/lecturers may wish to introduce only elements 1–20 at first and return to the remaining elements during the coverage of transition metals.
2(c) The blocks of the Periodic Table	The Periodic Table can be subdivided into four blocks (s, p, d and f) corresponding to the outer electronic configurations of the elements within these blocks.	f-orbitals are not assessable
2(d) Patterns in the Periodic Table explained by the filling of orbitals	The variation in first ionisation energy with increasing atomic number for the first 36 elements can be explained in terms of the relative stability of different electronic configurations, and so provides evidence for these electronic configurations. The relative values of first, second and subsequent ionisation energies can be explained in terms of the stabilities of different subshell electron configurations from which the electrons are being removed.	Graph of first IE v atomic number shows blips which gives good evidence of s and p orbitals being filled.

Content	Notes	Possible contexts and activities
3 Shape		
3 Valence shell electron pair repulsion theory	VSEPR theory provides a quick-to-apply method which allows the shape of a molecule or polyatomic ion to be predicted from the numbers of bonding electron pairs and non-bonding electron pairs. The arrangement of electron pairs is linear, trigonal planar, tetrahedral, trigonal bipyramidal and octahedral when the total number of bonding and non-bonding electron pairs is 2, 3, 4, 5 and 6, respectively. Electron pair repulsions decrease in strength in the order: non-bonding pair/non-bonding pair > non-bonding pair/bonding pair > bonding pair/bonding pair. These different strengths of electron pair repulsion account for slight deviations from expected bond angles in molecules such as NH_3 and H_2O.	Although VSEPR theory does not provide an accurate description of the actual molecular orbitals in a molecule, the shapes predicted are usually quite accurate. The RSC has links to sites allowing the 3D display of molecules with different numbers of bonding and non-bonding pairs. 💻
4 Transition metals		
4(a) Electronic configuration of transition metal atoms and ions	The d-block transition metals are metals with an incomplete d subshell in at least one of their ions. The filling of the d orbitals follows the aufbau principle, with the exception of chromium and copper atoms. These exceptions are due to a special stability associated with the d subshell being half filled or completely filled. When atoms from the first row of the transition elements form ions it is the 4s electrons which are lost first rather than the 3d electrons.	A striking display can be made by creating a set of sample bottles containing salts or compounds of the first 30 elements. If these are then positioned on an A1 or A2 sized Periodic Table poster it is striking that only the d-block compounds are coloured. Candidates may also notice that zinc compounds are white- indicating that, although lying in the central region of the Periodic Table- zinc is different from the transition metals. Scandium is also different since it forms only the 3+ ion which has no d electrons. A short ‘Brightstorm’ video on ‘Exceptions to Electron Configurations’ covers the electronic configurations of Cr and Cu. 💻

Content		Notes	Possible contexts and activities
4(b)	**Oxidation states of transition metals**	An element is said to be in a particular oxidation state when it has a specific oxidation number. The oxidation number can be determined by following certain rules. Transition metals exhibit variable oxidation states of differing stability. Compounds of the same transition metal but in different oxidation states may have different colours. Oxidation can be considered as an increase in oxidation number and reduction can be considered as a decrease in oxidation number. Compounds containing metals in high oxidation states tend to be oxidising agents whereas compounds with metals in low oxidation states are often reducing agents.	Zinc is used to reduce a solution of yellow ammonium vanadate(V) to a mauve solution containing vanadium(II) ions. The intermediate oxidation states of vanadium(IV) (blue) and vanadium(III) (green) are also seen. Details from the RSC website and also from RSC publication ‘Classic Chemistry Demonstrations’ No. 92 page 258 A similar experiment using zinc amalgam is also shown in a one minute video produced by the Open University. 💻 Can also do similar experiment with oxidation states of Mn. Bromfield Honors Chemistry video ‘Assigning Oxidation Numbers’ covers all the main points for assigning oxidation numbers. 💻 A website which is a series of questions and answers on oxidation numbers is available. It is good but fast. Best to be done as revision after oxidation numbers have been taught 💻
4(c)	**Transition metal complexes**	A complex consists of a central metal atom/ion surrounded by ligands. Ligands may be negative ions or molecules with non-bonding pairs of electrons which they donate to the central metal atom/ion forming dative bonds. Ligands can be classified as monodentate, bidentate up to hexadentate. The total number of bonds from the ligands to the central transition metal atom/ion is known as the co- ordination number. Complexes are written and named according to IUPAC rules.	Instructions for carrying out a microscale investigation into the chemistry of the transition elements, looking at their redox and precipitation reactions is available from the RSC website. 💻

Content	Notes	Possible contexts and activities
4(d) Coloured transition metal complexes	In a complex of a transition metal the d orbitals are no longer degenerate. The energy difference between subsets of d orbitals depends on the ligand. Colours of many transition metal complexes can be explained in terms of d-d transitions. Light is absorbed when electrons in a lower energy d orbital are promoted to a d orbital of higher energy. If light of one colour is absorbed, then the complementary colour will be observed.	An interesting introduction into colour in transition metal compounds is through the production of coloured glass. More can be found in the RSC publication 'Classic Chemistry Experiments' No.44 page 112 and on the RSC website. This allows candidates to make glass and then colour some glass using transition metal oxides 💻 RSC publication 'Classic Chemistry Demonstrations No. 93 page 261 shows different colours of nickel complexes with water and ethylenediamine as ligands in different ratios. The chemguide.co.uk website has pages which cover colours of transition metal complexes. Opportunity for candidates to find out about the spectrochemical series and investigate how the position of ligand in the series may affect the colour and paramagnetism of the complex. Prepare solutions containing Cu^{2+}(aq), Ni^{2+}(aq), Co^{2+}(aq). (Concentrations not important but concentrated enough to have characteristic colours). Add conc HCl to provide Cl^- ions as ligands and concentrated NH_3(aq) to provide NH_3 molecules as ligands. See colour changes due to differences in energy levels between d orbitals. Original solutions have H_2O molecules as ligands.
4(e) UV and visible spectroscopy of transition metal complexes	Ultra-violet and visible absorption spectroscopy involve transitions between electron energy levels in atoms and molecules where the energy difference corresponds to the ultra-violet and visible regions of the electromagnetic spectrum.	A UV-visible spectrometer measures the intensity of radiation transmitted through a sample, and compares this with the intensity of incident radiation. Determination of Mn in steel (PPA from unrevised AH) The wavelength ranges are approximately 200-400 nm for ultra-violet and 400-700 nm for visible.

Content	Notes	Possible contexts and activities
4(f) Catalysis by transition metals	Transition metals or their compounds act as catalysts in many chemical reactions. It is believed that the presence of unpaired d electrons or unfilled d orbitals allows intermediate complexes to form, providing reaction pathways with lower activation energies compared to the uncatalysed reaction. The variability of oxidation states of transition metals is also an important factor.	Hydrogen peroxide oxidises potassium sodium tartrate (Rochelle salt) to carbon dioxide. The reaction is catalysed by cobalt(II) chloride. The colour of the cobalt(II) chloride turns from pink to green (an activated complex), returning to pink again as the reaction dies down. Details of the experiment are available from the RSC publication ‘Classic Chemistry Demonstrations’ page 1 and also from their website. 💻 (The experiment may have been done at Higher but at AH discussion would involve oxidation states)