Higher National Unit specification

General information

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Unit code: H92Y 34

Superclass: RD

Publication date: July 2015

Source: Scottish Qualifications Authority

Version: 01

Unit purpose

This Unit is designed to enable learners to understand key aspects of inorganic chemistry, and of the different theories of chemical bonding. Learners will also develop practical skills in techniques relevant to inorganic chemistry. The Unit is suitable for learners studying at HNC level, and will provide the necessary underpinning knowledge and skills to enable progression to further study of inorganic chemistry at HND level or to seek employment in science based industries.

Outcomes

On successful completion of the Unit the learner will be able to:

1 Describe and explain aspects and consequences of atomic properties, and theories of chemical bonding.
2 Identify and explain properties of transition metal complexes.
3 Describe and apply aspects of electron transfer processes to redox reactions and electrochemical cells.
4 Perform practical experiments related to inorganic chemistry.

Credit points and level

1 Higher National Unit credit at SCQF level 7: (8 SCQF credit points at SCQF level 7)

Higher National Unit Specification: General information (cont)

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Recommended entry to the Unit

Entry is at the discretion of the centre, however it is recommended that learners should have completed the HN Unit H92X 34 *Fundamental Chemistry: Theory and Laboratory Skills* or equivalent, or have experience of Chemistry at Higher level.

Core Skills

Opportunities to develop aspects of Core Skills are highlighted in the support notes for this unit specification.

There is no automatic certification of Core Skills or Core Skill components in this unit.

Context for delivery

If this Unit is delivered as part of a Group Award, it is recommended that it should be taught and assessed within the subject area of the Group Award to which it contributes.

The Assessment Support Pack (ASP) for this Unit provides assessment and marking guidelines that exemplify the national standard for achievement. It is a valid, reliable and practicable assessment. Centres wishing to develop their own assessments should refer to the ASP to ensure a comparable standard. A list of existing ASPs is available to download from SQA's website **(http://www.sqa.org.uk/sqa/46233.2769.html)**.

Equality and inclusion

This Unit specification has been designed to ensure that there are no unnecessary barriers to learning or assessment. The individual needs of learners should be taken into account when planning learning experiences, selecting assessment methods or considering alternative evidence.

Further advice can be found on our website **www.sqa.org.uk/assessmentarrangements**.

Higher National Unit specification: Statement of standards

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (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.

Where evidence for Outcomes is assessed on a sample basis, the whole of the content listed in the Knowledge and/or Skills section must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed and different items should be sampled on each assessment occasion.

Outcome 1

Describe and explain aspects and consequences of atomic properties, and theories of chemical bonding.

Knowledge and/or Skills

- Atomic structure and atomic spectra
- Periodic and group trends
- Valence bond theory
- Molecular orbital theory
- Consequences of bond character
- Intermolecular forces and properties of covalent substances
- Coordination numbers of ionic lattices
- Physical properties and chemical characteristics of elements and compounds in relation to bonding

Outcome 2

Identify and explain properties of transition metal complexes.

Knowledge and/or Skills

- Formation of complexes
- Common geometries of complexes
- Nomenclature of complexes
- d-orbital splitting in complexes

Outcome 3

Describe and apply aspects of electron transfer processes to redox reactions and electrochemical cells.

Knowledge and/or Skills

- Electrochemical series, electrode potential and reaction feasibility
- Voltaic cells and calculation of electromotive force
- Electrolytic cells and calculation of quantity of products at electrodes
- Nernst equation and calculations involving electromotive force and equilibrium constants
- Balanced equations for redox reactions in acidic media
- Stoichiometric calculations for redox reactions

Outcome 4

Perform practical experiments related to inorganic chemistry.

Knowledge and/or Skills

- Inorganic chemistry experiments
- Working safely, within current health and safety regulations
- Consistent and accurate results
- Recording observations and results
- Evaluation skills
- Result analysis and conclusions

Evidence Requirements for this Unit

Written and/or oral recorded evidence for Outcomes 1–3 should be assessed using a holistic closed-book assessment under supervised conditions. The assessment will use a sampling approach to the Knowledge and/or Skills as detailed below. It is recommended that the assessment be completed within 90 minutes. Learners can only have access to the *SQA Databook for HN Chemistry* or any suitable replacement when sitting the assessment.

Written and/or oral recorded evidence for Outcome 4 should be assessed by production of a full laboratory report completion of an appropriate pro forma or a laboratory diary entry. An assessor's observation checklist could be used to record performance evidence of practical experiments.

Higher National Unit specification: Statement of standards (cont)

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Outcome 1

The assessment will sample six of the eight Knowledge and/or Skills items. Learners will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternative (re-sit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- Explain electronic configurations of atoms; perform calculations on atomic spectra.
- Explain period and group trends in atomic properties in terms of atomic structure.
- Apply valence bond theory to explain the shapes of given molecules.
- Apply molecular orbital theory to predict the bond order of diatomic molecules.
- Predict and explain bond character and consequences.
- Explain the physical properties of covalent substances on the basis of intermolecular forces.
- Predict and explain the coordination numbers in differing ionic lattices.
- Explain properties and chemical characteristics of elements and compounds using bonding and structure principles.

Outcome 2

The assessment will sample three of the four Knowledge and/or Skills items. Learners will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternative (re-sit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- Explain the formation of transition metal complexes in terms of metal-ligand bonding.
- Identify the common geometries of transition metal complexes.
- Apply IUPAC rules to nomenclature and formula of transition metal complexes.
- Explain the nature and effect of d-orbital splitting in transition metal complexes.

Outcome 3

The assessment will sample five of the six Knowledge and/or Skills items. Learners will not have prior knowledge of which items are being assessed. Those items which are not sampled must be covered in the alternative (re-sit) assessment.

Where an item is sampled, a learner's response will be judged satisfactory where the evidence shows that the learner can:

- Describe and predict the feasibility of redox reactions using either the electrochemical series or electrode potential.
- Describe voltaic cells in terms of electron flow and ion-electron half-equations; use electrode potential to calculate electromotive force under standard conditions.
- Describe electrolytic cells in terms of ion-electron half-equations; predict products at electrodes; perform calculations to determine amounts of products.
- Apply the Nernst equation to perform calculations involving electromotive force and equilibrium constants.
- Produce balanced equations for redox reactions in acidic media.
- Perform stoichiometric calculations based on redox reactions.

Outcome 4

Learners will perform a minimum of two practical experiments, the content of which will be related to Outcomes 1–3. A learner's response will be judged satisfactory where the evidence shows that the learner can achieve all of the following:

- Follow instructions to perform experiments related to inorganic chemistry.
- Work in a safe manner regarding current health and safety regulations.
- Achieve consistent and accurate results.
- Record experimental observations and results clearly and accurately.
- Evaluate validity of results in terms of sources of and values of experimental errors.
- Analyse results correctly and state valid conclusions.

An assessor observation checklist will be used to record the learner's performance of the practical work in line with given instructions and health and safety requirements.

Learners may report results either by production of a full laboratory report, completion of an appropriate pro forma or a laboratory diary entry. Where a pro forma approach is deployed, the pro forma will not present information or assistance to the learners on how to correctly perform calculations, analyse experimental results or experimental errors. Learners will be expected to perform such activities independently on the basis of the experimental data. Where a laboratory diary approach is deployed, the laboratory diary must meet all of the requirements of a pro forma (in particular an evaluation of experimental errors), as set out in the Understanding Standards materials.

Where a learner does not perform an assessed practical experiment to the required standard, they will be given the chance to either reattempt the same practical experiment, or

to undertake a different practical experiment of similar complexity. Where a laboratory report, pro forma or laboratory diary does not meet the required standard, then the learner will be given a single opportunity to re-draft. If the required standard is still not attained, then an alternative practical experiment will be set.

Higher National Unit Support Notes

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Unit Support Notes are offered as guidance and are not mandatory.

While the exact time allocated to this Unit is at the discretion of the centre, the notional design length is 40 hours.

Guidance on the content and context for this Unit

This Unit is intended as part of the framework for HNC/HND Applied Sciences and HND Applied Chemical Sciences but may be suitable for inclusion in other HN Science and Engineering awards. It is designed to develop the theoretical and practical aspects of inorganic chemistry introduced in the HN Unit H92X 34 *Fundamental Chemistry: Theory and Laboratory Skills*, and also to introduce learners to theories of bonding and to transition metal complexes.

Outcome 1 — Describe and explain aspects and consequences of atomic properties, and theories of chemical bonding

- Determination of electron configurations. Application of Aufbau Principle, Pauli Exclusion Principle, Hund's Rule, Quantum Numbers. Explanation and evaluation of electronic transitions in atomic spectra, including calculations relating wavelength to energy.
- Period in and group trends in atomic properties including atomic covalent and ionic radius, ionisation energies, electron affinity and electronegativity.
- Application of valence bond theory, including common hydridisation schemes (sp^1, sp^2, sp^3, dsp^2, d^2sp^3, dsp^3) to predict and explain molecular geometries, including effects of lone pairs eg in ammonia and water. Explanation of construction of double and triple bonds in term of π and σ.
- Application of molecular orbital theory to predict and explain bond order and existence/non-existence of diatomic species, eg H_2, H_2^{1-}, H_2^{2-}, He_2, He_2^{1+} ,etc.
- Description and representation of metallic, ionic and covalent bond types. Prediction of intermediate bond types in terms of electronegativity and Fajan's rules, and consequences in terms of properties.
- Intermolecular forces (van der Waals forces, dipole-dipole forces and hydrogen bonds) related to physical properties of elements and compounds.
- Common crystal lattices explained in terms of coordination numbers and close-packing arrangements eg sodium chloride, caesium chloride, cubic close-packing, hexagonal close-packing, etc.
- The main chemical and physical characteristics of elements considered group by group and illustrated by the formation of key compounds, eg chlorides, oxides and hydrides. The physical and chemical properties of said compounds described and explained in terms of bonding and structure in these compounds.

Higher National Unit Support Notes

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Outcome 2 — Identify and explain properties of transition metal complexes

This Outcome is intended to furnish learners with a brief introduction to the chemistry of transition metal complexes, and thereby provide a link to further study at SCQF level 8.

- Formation of complexes described in terms of dative covalent bonding from ligands to metal centre. Common neutral and anionic ligands will be introduced, eg halides, H2O, NH3.
- The common geometries of complexes, square planar, tetrahedral and octahedral and how to draw 3D representations of them.
- The IUPAC nomenclature of complexes containing simple monodentate ligands.
- The effects of ligand fields in producing d-orbital splitting in complexes, and the manifestation of this in absorbance of visible light. 'Colour wheel' model used to explain observed colours.

Outcome 3 — Describe and apply aspects of electron transfer processes to redox reactions and electrochemical cells

- Reactivity and the electrochemical series; standard electrode potentials; use of these to predict feasibility and directions of reactions under standard conditions.
- Voltaic and electrochemical cells and calculations of electromotive force under standard conditions. Applications in simple batteries.
- Electrolytic cells; prediction of products at electrodes; calculation of amounts of products discharged at electrodes (mass of solid, volume of gas). Applications in electroplating and industrial manufacturing processes.
- Application of the Nernst equation to perform calculations relating standard electrode potential to equilibrium constants and free energy, electrode potentials under non-standard conditions, concentration cells, etc.
- Writing and balancing ion-electron equations and overall redox equations in acidic media.
- Stoichemistry of redox reactions: performing calculations on data from redox titrations, etc.

Outcome 4 — Perform practical experiments related to inorganic chemistry

Guidance on suitable practical experiments for assessment purposes is given elsewhere in this document. However, it is envisaged that learners will also participate in a range of other practical experiments which will both develop their laboratory skills and support the theory covered in Outcomes 1–3.

In carrying out such activities, learners should follow Good Laboratory Practice (GLP) and carry out or be familiar with the risk and Control of Substances Hazardous to Health (COSHH) assessments on all procedures undertaken. Opportunities should be taken to develop awareness of the sources of experimental error and of the accuracy of measurements, with quantification of errors where possible.

Higher National Unit Support Notes (cont)

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Guidance on approaches to delivery of this Unit

There is no particular order in which Outcomes 1–3 would be best delivered. It is envisaged that laboratory work and demonstrations will feature across the delivery of each of the Outcomes, and that the assessed practical experiments for Outcome 4 will be undertaken in similar timeframe to the underpinning theory.

It is envisaged that delivery of Outcome 1 could commence with coverage of atomic structure and an understanding of electronic transitions in atomic spectra, in which practical experiments could play a part, followed by a review of periodic trends. In the delivery of valence bond and molecular orbital theories of bonding, it is important that learners grasp the pros and cons of the two approaches. At this level, only a very limited exposition of molecular orbital theory will be given, but it is important that learners are aware of the principles of the approach, and how it can address the shortcoming in valence bond theory. In the delivery of intermolecular bonding it is to be expected that most learners will already possess knowledge from SCQF level 6. This could be built on further by the researching of particular substances and applications. To help ensure that learners attain a good grasp of crystal structures, it is suggested that some time is spent on modelling exercises of close-packing arrangements.

Outcome 2 is intended to provide a brief introduction to the topic of transition metal complexes, to give learners a brief overview of this important area of chemistry, and to familiarise them with key aspects for potential further study at SCQF level 8.

Outcome 3 is suitable for delivery in an experimental context which emphasises the practical applications of electrochemistry and which develops the ability to apply theoretical knowledge to practical problems. Learners could construct electrochemical cells, investigate rates of corrosion etc and relate observations to underpinning theory. Industrial visits or industrial case studies could play a part in this Outcome.

It is envisaged that Outcome 4 will be delivered alongside the theoretical based Outcomes 1–3. A range of practical experiments could be utilised to both support understanding of the underlying theory and to prepare learners for undertaking the assessed practical experiments. Aspects suitable for experimental investigation might include periodic trends, model building, visible spectrometry of transition metal complexes, electrochemical cells, corrosion, redox titrations, etc.

Guidance on approaches to assessment of this Unit

Evidence can be generated using different types of assessment. The following are suggestions only. There may be other methods that would be more suitable to learners.

Outcomes 1–3 could be assessed by a single holistic closed-book assessment with an appropriate cut-off score that covers the sampling requirements as detailed in the Evidence Requirements. Assessment should be carried out in supervised conditions, and it is recommended that the assessment be completed within 90 minutes. Learners can only have access to the *SQA Databook for HN Chemistry* or any suitable replacement when sitting the assessment.

Higher National Unit Support Notes (cont)

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Where evidence of Outcomes 1–3 is assessed by sampling, the whole of the content listed in the Knowledge and/or Skills must be taught and available for assessment. Learners should not know in advance the items on which they will be assessed, and different items should be sampled on each assessment occasion. Any items not sampled in the first assessment must be included in the alternative (re-sit) assessment.

In Outcome 4 learners are required to undertake two assessed practical experiments, the content of which will be related to Outcomes 1–3. Examples of suitable experiments are given below. However, this list is not prescriptive, and other practical experiments of similar complexity may be used by the centre.

Suitable practical experiments for Outcome 1 are:

- experiments to investigate the chemical and physical properties of a series of compounds, such as the acid/base properties of oxides or the reactions of chlorides with water.
- comparing the properties of a group of elements.
- preparation of compounds in various oxidation states, eg tin(II) and tin(IV) iodide.

Suitable practical experiments for Outcome 2 are:

- gravimetric determination of nickel using dimethylglyoxime.
- preparation of potassium trioxalatoferrate (III).
- assigning the position of ligands in the spectrochemical series by analysing the UV/Vis spectra of complexes.

Suitable practical experiments for Outcome 3 are:

- quantitative electrolysis, eg relating volume of hydrogen gas produced at cathode to mass loss at anode.
- redox titrations, eg determination of Iron (II) in an unknown salt.

Assessed practical experiments will usually be performed individually. However, there may be some experiments that are suitable to be undertaken in pairs or small groups. If this is the case then the assessor should ensure that all participants are actively involved and are able to adequately demonstrate the required skills.

An exemplar instrument of assessment with marking guidelines has been produced to indicate the national standard of achievement at SCQF level 7.

Centres are reminded that prior verification of centre-devised assessments would help to ensure that the national standard is being met. Where learners experience a range of assessment methods, this helps them to develop different skills that should be transferable to work or further and higher education.

Higher National Unit Support Notes (cont)

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Opportunities for 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 learner evidence and that conditions of assessment as specified in the Evidence Requirements are met, regardless of the mode of gathering evidence. The most up-to-date guidance on the use of e-assessment to support SQA's qualifications is available at **www.sqa.org.uk/e-assessment**.

Opportunities for developing Core and other essential skills

The delivery and assessment of this Unit will provide learners with the opportunity to develop the Core Skills of Numeracy and *Problem Solving* at SCQF level 6, and *Information and Communication Technology (ICT)* at SCQF level 4.

Problem Solving — Reviewing and Evaluating at SCQF level 6

Following assessed practical experiments learners will be required to review and evaluate the effectiveness of the exercise with a thorough interpretation of random and systematic sources of error. They will be required to reach sound conclusions on the basis of the data collected and the inherent errors.

Information and Communication Technology (ICT) — Providing/Creating Information at SCQF level 4

Learners will make effective and appropriate use of ICT packages to produce laboratory reports or pro formas in an appropriate format. Packages used will likely include word processing, spreadsheets, and specialist chemical structure software.

Sustainability

Sustainability can be embedded in delivery of the Unit in a variety of ways. For example, by encouraging minimum usage, correct disposal procedures and possibly recycling (eg of solvents) during practical experiments.

History of changes to Unit

Version	Description of change	Date

General information for learners

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

This section will help you decide whether this is the Unit for you by explaining what the Unit is about, what you should know or be able to do before you start, what you will need to do during the Unit and opportunities for further learning and employment.

This is a 1 credit Unit at SCQF level 7, which you are likely to be studying as part of the first year of an HNC/HND Science programme. Before progressing to this Unit it would be beneficial to have completed the HN Unit H92X 34 *Fundamental Chemistry: Theory and Laboratory Skills*, where you will have learned underpinning aspects of inorganic chemistry and developed your practical skills. There will be a strong emphasis on the importance of experimental data in understanding chemical principles, and on the applications of chemical knowledge in practical situations.

On completion of the Unit you should be able to:

1 Describe and explain aspects and consequences of atomic properties, and theories of chemical bonding.
2 Identify and explain properties of transition metal complexes.
3 Describe and apply aspects of electron transfer processes to redox reactions and electrochemical cells.
4 Perform experiments related to inorganic chemistry.

Outcome 1

In this Outcome you will cover aspects of atomic structure, in particular electron configurations, and utilise this to explain the properties of elements and trends in the periodic table.

You will also consider two alternative theories of covalent bonding — valence bond theory and molecular orbital theory. You will consider the strengths and the weaknesses of the two approaches, and use them to make predictions on the properties of substances and the existence/non-existence of potential molecules.

The prediction of bond character and the impact on properties of substances will be covered, including a detailed consideration of the different types of intermolecular forces that exist in substances.

The structure of crystal lattices will also be investigated, where you will gain knowledge and understanding of the different lattice structures that are formed by metallic and ionic substances.

Outcome 2

In this Outcome you will gain an understanding of essential aspects of transition metal complexes. You will learn about the formation and bonding in these important substances, and how to apply nomenclature rules to name them. You will also gain an understanding of the electron arrangements in these substances, and how this explains the origins of their colour chemistry.

General information for learners

Unit title: Inorganic Chemistry: Theory and Laboratory Skills (SCQF level 7)

Outcome 3

In this Outcome you will study the principles of oxidation and reduction to develop your understanding of how electron transfer processes can be harnessed in practical ways. You will see how redox reactions can be used to drive the production of electrical energy in voltaic cells such as batteries and fuel cells. Electrical energy can be used to bring about chemical reactions in applications such as corrosion protection, industrial manufacture and electroplating. You will apply chemical principles to perform calculations related to voltaic cells and electrolytic processes.

Also covered in this Outcome will be the stoichemistry of redox reactions, and the necessary underpinning theory to apply these as analytical tools.

Outcome 4

In this Outcome you will undertake practical experiments, based on the content of Outcomes 1–3.

During this practical work, you will also be expected to develop good laboratory practices as well as improve your skills of manipulation, observation and measurement. You will be encouraged to develop safe working practices and to strive constantly to improve the accuracy and reliability of your results. The reporting and analysis of experimental data is an important aspect of the practical sessions.

Assessment

For Outcomes 1 to 3 you will take a closed-book, end of Unit assessment.

Outcome 4 will be assessed after you have learned the necessary practical skills, and will take the form of two practical experiments, for which you will report your results either in full laboratory reports, completion of pro forma reports or a laboratory diary entry. You must produce a full laboratory report for at least one practical experiment.

Core Skills

You will have opportunities to develop the Core Skills of *Problem Solving* at SCQF level 6, and *Information and Communication Technology (ICT)* at SCQF level 4.