Higher National Unit specification

General information

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

Unit code: H939 35

Superclass: RD

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Version: 01

Unit purpose

This Unit is designed to enable learners to understand key aspects of transition metal chemistry, encompassing the chemistry and structural properties of d-metal elements, compounds and complexes, and the concepts of bonding to the spectral and magnetic properties of coordination compounds. Learners will also develop practical skills in techniques relevant to transition metal chemistry. The Unit is suitable for learners studying at HND level, and will provide the necessary underpinning knowledge and skills to enable progression to further study of transition metal chemistry at degree level or to seek employment in science based industries.

Outcomes

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

1 Apply nomenclature and isomerism principles of transition metal complexes.
2 Describe bonding models and properties of transition metal complexes.
3 Describe applications and redox chemistry of transition metals.
4 Perform practical experiments related to transition metal chemistry.

Credit points and level

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

Higher National Unit Specification: General information (cont)

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

Recommended entry to the Unit

Entry is at the discretion of the centre, however it is recommended that learners should have completed the HN Units H92X 34 *Fundamental Chemistry: Theory and Laboratory Skills* and H92Y 34 *Inorganic Chemistry: Theory and Laboratory Skills* or equivalent.

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: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

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

Apply nomenclature and isomerism principles of transition metal complexes.

Knowledge and/or Skills

- IUPAC nomenclature
- Isomerism: geometric, optical, inkage

Outcome 2

Describe bonding models and properties of transition metal complexes.

Knowledge and/or Skills

- Crystal field theory and d-d splitting
- Valence bond theory
- UV/Vis spectroscopy and colours
- Magnetism
- Chelate effect and thermodynamics of stability
- π-donor/acceptor ligands and complex stability

Outcome 3

Describe applications and redox chemistry of transition metals.

Knowledge and/or Skills

- Redox chemistry: Latimer or Frost Diagrams
- Analytical chemistry
- Applications

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

Outcome 4

Perform practical experiments related to transition metal chemistry.

Knowledge and/or Skills

- Transition metal 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, or by completion of an appropriate pro forma. An assessor's observation checklist could be used to record performance evidence of practical experiments.

Outcome 1

The assessment will cover all of the Knowledge and/or Skills items. A learner's response will be judged satisfactory where the evidence shows that the learner can:

- Apply IUPAC nomenclature to derive names from formulae of complexes and vice versa.
- Apply principles of isomerism to produce and identify geometric, optical and linkage isomers.

Higher National Unit specification: Statement of standards (cont)

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

Outcome 2

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 alternate (re-sit) assessment.

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

- Apply crystal field theory to describe d-d splitting in complexes; perform calculations to determine crystal field stabilisation energies.
- Apply valence bond theory to predict the geometry of transition metal complexes.
- Describe UV/Vis spectra and colours of complexes in terms of electron configurations and selection rules.
- Perform calculations relating to the paramagnetism of complexes.
- Describe the origin of the chelate effect in terms of thermodynamics of stability.
- Describe/predict the effect of π-donor/acceptor ligands on complex stability.

Outcome 3

The assessment will sample two of the three 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 alternate (re-sit) assessment.

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

- Predict the redox chemistry of transition metal species via application of Latimer or Frost Diagrams.
- Describe analytical chemistry involving transition metals.
- Describe applications involving transition metals in industrial, medicinal or any other suitable field.

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 transition metal 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.

Higher National Unit specification: Statement of standards (cont)

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

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 must report one of the two practical experiments by production of a full laboratory report. Learners may report the remaining practical experiment by production of a full laboratory report or by completion of an appropriate pro forma. 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 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 or pro forma does not meet 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: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

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 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 transition metal chemistry, introduced in the HN Unit H92Y 34 *Inorganic Chemistry: Theory and Laboratory Skills*.

Outcome 1 — Apply nomenclature and isomerism principles of transition metal complexes

Application of IUPAC nomenclature to determine chemical formulae of complexes from names and vice versa.

Predicting, recognising and naming the isomeric possibilities for transition metal complexes, including those with bidentate ligands. This should include geometric (cis-trans and fac-mer) optical and linkage isomerism.

Outcome 2 — Describe bonding models and properties of transition metal complexes

Crystal field theory and d-d splitting in transition metal complexes. Crystal field stabilisation energies, spectrochemical series, high spin and low spin configurations.

Valence bond theory to predict the geometry of transition metal complexes (octahedral, quare planar and tetrahedral).

UV/Vis spectra of one electron systems in terms of location, absorbance and shape using the selection rules. Predict and explain using the spectrochemical series, red or violet shifts in location with change of ligand.

Magnetic properties of complexes — paramagnetism and diamagnetism. Calculation of spin only magnetic moments.

The chelate effect — applications of thermodynamics principles to explain the unusual stability of complexes with multidenate ligands.

π-donor/acceptor ligands and their effects on stabilising metal centres of high or low oxidation states.

Outcome 3 — Describe applications and redox chemistry of transition metals

The redox chemistry of transition metal species in aqueous solution via application of Latimer or Frost Diagrams. Prediction of disproportionation and coproportionation. Calculation of E_o values between non-adjacent species in series.

Analytical chemistry involving transition metals. Use of EDTA. Selection of indicators and the reasons for prescribed pH conditions and calculations in volumetric analysis. Use of precipitating agents (especially organic and organometallic compounds) in gravimetric analysis. Ideal properties of precipitants and calculation of results.

Applications involving transition metals in industrial, medicinal or any other suitable field. There are many aspects which could be covered. A brief synopsis of a small number will serve to develop awareness in the learner of the diverse applicability of this area of chemistry.

Outcome 4 — Perform practical experiments related to transition metal 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.

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 a similar timeframe to the underpinning theory.

It is envisaged that delivery of Outcome 1 could commence with a general overview of the nature of transition metal complexes, including a recap of electron configuration, common ligands (mono- and polydenate-) and dative bond formation. A brief synopsis of some important applications of transition metal complexes would be beneficial at this stage. Learners could be instructed on how to determine the valence of the metal in a complex. IUPAC nomenclature rules could then be covered in detail, with learners being required to derive both names and formulae. The topic of isomerism may be best introduced by means of a recap of learners' existing knowledge of organic chemistry, and then progressing to consider both the equivalent and the non-equivalent examples from transition metals complexes.

Aspects covered should be geometric (cis-trans and fac-mer), optical and linkage isomerism. It is expected that model building exercises would play a valuable role in delivery of this topic.

Outcome 2 could commence with a description of crystal field theory and its effect on d-d splitting in transition metal complexes. Learners would be required to calculate crystal field stabilisation energies, and to understand the concept of high spin and low spin configurations and the effect of the spectrochemical series on these.

The valence bond theory topic could first be delivered with a recap of material on main group element, and then proceed to cover the VBT model as applied to transition metal complexes. Learners should be able to explain and predict common geometries.

The origin of the UV/Vis spectra could be explained in terms of d-d splitting, with a brief synopsis of the appropriate selection rules. There are many applications which may be used to enliven this topic eg gemstones, pigments. The prediction and explanation of red or violet shifts in terms of spectrochemical series will particularly lend itself to practical based approaches to delivery.

The magnetic properties of complexes would consider the origin of both paramagnetism and diamagnetism, with calculation of spin only magnetic moments for the former. Learners should be able to identify high and low spin configurations via the application of experimental magnetic data.

The additional stability of complexes with multidentate ligands could be explained in terms of the chelate effect. This will build upon learners' understanding of entropy and equilibrium constants.

The effects π-donor/acceptor ligands on stabilising metal centres of high or low oxidation states should be covered in brief, with learners able to identify ligands of each type and describe/predict their effects.

In Outcome 3 learners will be introduced to Latimer and Frost Diagrams as tools for presenting and interpreting the redox chemistry of transition metal species in aqueous solutions. Learners should be able to construct such diagrams, and use them to predict disproportionation and coproportionation, and calculate E_o values between non-adjacent species in series.

The analytical chemistry of transition metals is a very large topic, and only a brief overview of some key aspects should be covered. The use of EDTA as a complexation agent should be covered, and the selection of indicators and the reasons for prescribed pH conditions and calculations in volumetric analysis should also be covered. Further topics to be covered could be the use of precipitating agents (especially organic and organometallic compounds) in gravimetric analysis and the ideal properties of precipitants and calculation of results.

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

Applications involving transition metals in industrial, medicinal or any other suitable field. There are many aspects which could be covered. A brief synopsis of a small number will serve to develop awareness in the learner of the diverse applicability of this area of chemistry. Examples could include Wilkinson's catalysts, cis-platin, haemoglobin, etc.

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 students for undertaking the assessed practical experiments. Aspects suitable for experimental investigation might include visible spectra of complexes, complexiometric titrations, redox potentials and modelling exercises.

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.

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 are:

- Complexation titration using EDTA to determine transition metal content of a given substance.
- Determination of nickel using dimethylglyoxime.
- Preparation of $[Ti(H_20)_6]^{3+}$ and $[TiCl_6]^{3-}$ and run the UV spectra. Account for location, shape, absorbance of each and the differences between them.
- Prepare the cis- and trans- isomers of K $[Cr(C_2O_4)_2(H_2O)_2]$. Test each isomer for purity (dil. NH_4OH).
- Determination of the dissociation constant of the aqua ligand in $[Co(NH_3)_5H_2O]^{3+}$

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

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 8.

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.

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 *Problem Solving* at SCQF level 6, *Numeracy* at SCQF level 5 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.

Numeracy — Using Number at SCQF level 5

Learners will be required to decide on steps to be carried out and in what order to solve problems or situations, where the required processes are not obvious, eg calculations involving reaction stoichiometry or calculations of percentage yield.

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

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. Learners will also be required to utilise internet search engines to source information on research topics.

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

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.

General information for learners

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

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 8, which you are likely to be studying as part of the second year of an HND Science programme. Before progressing to this Unit it would be beneficial to have completed the HN Units H92X 34 *Fundamental Chemistry: Theory and Laboratory Skills* and H92Y 34 *Inorganic Chemistry: Theory and Laboratory 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 Apply nomenclature and isomerism principles of transition metal complexes.
2 Describe bonding models and properties of transition metal complexes.
3 Describe applications and redox chemistry of transition metals.
4 Perform practical experiments related to transition metal chemistry.

Outcome 1

In this Outcome you will encounter basic aspects of transition metal complex formation. You will then progress to the application of IUPAC nomenclature to determine chemical formulae of complexes from names and vice versa.

You will also cover the types of isomerism which arise in transition metal complexes, and their nomenclatures.

Outcome 2

In this Outcome you will cover essential aspects of transition metal complex formation and properties. This will include crystal field theory and d-d splitting in transition metal complexes, crystal field stabilisation energies, the spectrochemical series and high spin and low spin configurations. You will learn how the valence bond theory can be applied to predict the geometry of transition metal complexes (octahedral, square planar and tetrahedral).

The colour chemistry of transition metal complexes, including UV/Vis spectra of one electron systems in terms of location, absorbance, and shape using the selection rules will also be covered.

You will also learn about the magnetic properties of complexes — paramagnetism and diamagnetism — and how to calculate spin only magnetic moments. In addition, aspects affecting complex stability, including the chelate effect and π-donor/acceptor ligands will be covered.

General information for learners (cont)

Unit title: Transition Metal Chemistry: Theory and Laboratory Skills (SCQF level 8)

Outcome 3

In this Outcome you will learn about the redox chemistry of transition metal species in aqueous solution via application of Latimer or Frost Diagrams, and how to predict disproportionation and coproportionation.

You will cover aspects of analytical chemistry involving transition metals, such as use of EDTA and use of precipitating agents in gravimetric analysis.

You will also learn about important applications involving transition metals in industrial or medicinal fields.

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 also 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, or by completion of pro forma reports.

Core Skills

Although there is no automatic certification of Core Skills in the Unit, you will have opportunities to develop the Core Skills of *Problem Solving* at SCQF level 6, *Numeracy* at SCQF level 5 and *Information and Communication Technology (ICT)* at SCQF level 4.