Higher National Unit specification

General information

Unit title: Applications of Transition Metal Compounds (SCQF level 8)

Unit code: H92M 35

Superclass: RD

Publication date: May 2015

Source: Scottish Qualifications Authority

Version: 02

Unit purpose

This Unit is designed to enable learners to understand key aspects of the role and application of transition metal elements and compounds as catalysts and in biochemical and pharmaceutical systems. Learners will also develop practical skills in techniques relevant to the applications of transition metal compounds. 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 compounds 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 Explain the role of transition metal compounds in catalytic, biochemical and pharmaceutical systems.
2 Perform practical experiments related to the role of transition metal compounds.

Credit points and level

1 Higher National Unit credit at SCQF level 8: (SCQF credit points at 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 Unit H939 35 *Transition Metal Chemistry: Theory and Laboratory Skills* or equivalent, or have prior knowledge of co-ordination Chemistry.

Higher National Unit specification: General information (cont)

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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

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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

Explain the role of transition metal compounds in catalytic, biochemical and pharmaceutical systems.

Knowledge and/or Skills

- Chemistry of transition metal elements
- Inorganic reaction mechanisms: insertion reactions, ligand exchange reactions, redox reactions, oxidative addition, reductive elimination reactions, catalysed cross coupling reactions
- Transition metal complexes as catalysts
- Biochemical systems involving transition metal elements
- Pharmaceutical applications of transition metal elements

Outcome 2

Perform practical experiments related to the role of transition metal compounds.

Knowledge and/or Skills

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

Higher National Unit specification: Statement of standards (cont)

Unit title: Applications of Transition Metal Compounds (SCQF level 8)

Evidence Requirements for this Unit

Written and/or oral recorded evidence for Outcome 1 should be assessed using a closed-book assessment under supervised conditions. 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 2 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:

- Explain the chemistry of transition metal elements; explain trends in oxidation states, through Latimer or Frost diagrams. Elements should be taken from rows one, two or three.
- Explain insertion reactions; explain one other inorganic reaction mechanism from the following: ligand exchange reactions, redox reactions, oxidative addition, reductive elimination reactions, catalysed cross coupling reactions; explain the use of catalysts in the reaction mechanism of alkene hydrogenation to form stereospecific alkane products.
- Explain the roles of transition metal complexes in catalysis.
- Explain transition metal elements in a biological system.
- Explain transition metal elements in a pharmaceutical application.

Outcome 2

Learners will perform a minimum of two practical experiments, the content of which will be related to Outcome 1. 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 compounds
- 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.

Higher National Unit specification: Statement of standards (cont)

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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 experiments independently on the basis of the experimental data.

Where a learner does not perform the 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 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: Applications of Transition Metal Compounds (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 Chemical Sciences but may be suitable for inclusion in other HN Science awards. It is designed to develop the theoretical and practical aspects of inorganic chemistry introduced in the HN Unit H939 35 *Transition Metal Chemistry: Theory and Laboratory Skills*, and also to introduce learners to transition metal elements and their importance in the modern economy as catalysts in industry, biochemical processes and pharmaceutical processes.

Outcome 1 — Explain the role of transition metal compounds in catalytic, biochemical and pharmaceutical systems

- The detailed chemistry of at least two selected transition metal elements from rows one, two or three. Trends in oxidation states within the transition metal elements, Latimer diagrams or other oxidation state diagrams.

- Inorganic reaction mechanisms including insertion reactions, ligand exchange reactions, redox reactions, oxidative addition reactions, reductive elimination reactions and catalysed cross coupling reactions.

Specific application knowledge in the subject should cover at least three specific applications over the three major areas:

- Specific industrial catalytic systems of transition metals that have been key in developing the modern world such as; homogeneous/heterogeneous Zeigler-Natta catalysts and polymer production, alkene hydrogenation with Wilkinson's Catalyst, the Oxo synthesis homogeneous catalysis for the production of aldehydes from alkenes, the Monsanto and Cativa Acetic acid processes, the Fischer Tropsch process, conversion of synthesis gas to aliphatic hydrocarbons over transition metal catalysts iron, cobalt or nickel. This list is not exhaustive and centres should be free to select appropriate topics that they can adequately resource.

- Biochemical applications of transition metals that are key to fundamental biological processes such as; Iron in Haemoglobin, Cobalt in Vitamin B12, Vanadium in Haemovanadin, Manganese in Dehydrogenases, Nickel in Metallothioneins and Tungsten in Oxidase Enzymes. This list is not exhaustive and centres should be free to select appropriate topics that they can adequately resource.

- Pharmaceutical examples of transition metals such as; the cytotoxicity of Titanium, anti-cancer properties of Ruthenium, application of Yttrium and Zirconium in orthopaedic and dental implants. This list is not exhaustive and centres should be free to select appropriate topics that they can adequately resource.

Outcome 2 — Perform practical experiments related to the role of transition metal compounds

Guidance on the 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 Outcome 1.

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

It is envisaged that Outcome 2 will be delivered alongside the theoretical based Outcome 1. 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.

Delivery of Outcome 1 could begin with an overview of the main properties and trends of the transition metal elements, specifically the formation of octahedral and tetrahedral complexes. This could be delivered using practical experiments, such as observational activities on the reactions of Cr, Fe and Cu. However other suitable alternatives could be used. On-line simulations showing transition metal trends in detail and worksheets designed for learners to complete missing information could also be considered.

Delivery could then move onto the three key established reaction mechanisms:

- Ligand Substitution (Exchange): $ML_6 + Y \longrightarrow ML_5Y + L$
- Redox Reactions: Involving electron exchange between two metal complexes
- Oxidative Addition: $ML_4 + X_2 \longrightarrow ML_4X_2$ M Oxidation states increases by two

Learners could categorise the complexes thermodynamically as stable or unstable and describe the kinetic activity of a complex in terms of labile or inert. Delivery should focus on the need to study the mechanisms of reactions through reactions slow enough to follow.

Associative, dissociative and interchange substitution reactions could then be discussed and potential solvent effects considered. Proof of dissociative substitution could be given by annotation of $[Co(NH_3)5H_2O]^{3+}$ as an example.

The two REDOX reaction mechanisms could then be discussed and Inner and Outer sphere defined before moving on to discuss and define oxidative addition mechanisms with the three main classes of oxidative addition substrates being covered: non-electrophilic, electrophilic and intact.

Delivery could then be extended to introduce the roles of transition metal complexes in homogeneous catalysis using Wilkinson's Catalyst, Zeigler-Natta catalyst plus any other suitable examples. Wilkinson's Catalyst could be exemplified by the synthesis of Wilkinson's Catalyst or the reaction of Wilkinson's Catalyst with Aldehydes.

The role of transition elements in biological systems could then be covered, including Fe in Haemoglobin, Co in Vitamin B12, etc. There are many examples to choose from and delivery could be considered in conjunction with other Chemistry Units that learners are undertaking, or specific interests that learners may have. Some examples include: binding of the zinc ion and the catalytic mechanism involving the zinc ion in Carboxypeptidase, involved in the digestion of proteins, the structural formulae and role of Chlorophyll a and b structurally similar to and produced through the same metabolic pathway as porphyrin pigments such as haemoglobin and myoglobin. The nature and function of deoxyhemoglobin and oxyhemoglobin. The structure and aromatic nature of porphines and porphyrins could then be covered as well as modelling of the structure with picket and capped structures.

Delivery could then focus on the role of transition metals in pharmaceuticals through the exemplification of the mechanism of silver toxicity and its reliance on the interaction between the metal and cellular membranes. Silver binds either to membrane bound proteins or the lipid bilayer, causing ion leakage and cell rupture and disruption of the function of mitochondrial membranes. This is just one pharmaceutical application of transition metals, any other suitable application could be considered.

Pharmaceutical applications of transition metals could be exemplified by practical experiments such as the bacterial sensitivity to silver nanoparticles, through an agar plate. Other experiments could involve the measurement of the rate of respiration of yeast in the presence of different forms of silver. Alternatively the chemistry and material properties of titanium could be considered and its selection and suitability in orthopaedic biomedical applications.

Guidance on how to interpret chemical information related to this Unit should be always at hand for the learner.

For Outcome 2, a range of practical experiments could be utilised to both support understanding of the underlying theory in Outcome 1 and to prepare learners for undertaking the assessed practical experiments. Aspects suitable for experimental investigation might include simple observational exercises looking at reactions of selected transition elements, to reaction rate experiments looking at ligand exchange reactions. Given the expense of the chemicals and the nature of the practical work, it may be difficult to deliver specific laboratory exercises on biological/pharmaceutical systems and homogeneous catalysis.

However, centres could develop a series of practical experiments which demonstrate the range of properties shown by transition elements.

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.

Outcome 1 could be assessed by a single closed-book assessment with an appropriate cut-off score. 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.

In Outcome 2 learners are required to undertake two assessed practical experiments, the content of which will be related to Outcome 1. 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:

- Acylation of ferrocene
- Reduction of acetylferrocene
- Preparation of Co(salen)
- Determination of oxygen absorption by Co(salen)
- Kinetics of ligand exchange — nitrite with aquapentammine cobalt(III) ion
- Acid dissociation constant of aquapentammine cobalt(III) ion
- Synthesis of Wilkinson's Catalyst
- Reaction of Wilkinson's Catalyst with Aldehydes

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.

Higher National Unit Support Notes (cont)

Unit title: Applications of Transition Metal Compounds (SCQF level 8)

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.

Numeracy — Using Numbers at SCQF level 6

Learners will be required to decide on the steps and operations to solve complex problems, carrying out sustained and complex calculations, eg performing calculations related to quantitative calculations on yields such as in the reaction of Wilkinson's Catalyst with Aldehydes.

Problem Solving — Reviewing and Evaluating SCQF level 6

Following the 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. Learners 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 in an appropriate format. Packages used will likely include word processing, spreadsheets, powerpoint, 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
2	Amendment to first Evidence Requirement under Outcome 1 on page 4. Previous version read 'Explain the chemistry of two transition metal elements; explain trends in oxidation states, through Latimer or Frost diagrams.' Updated sentence reads 'Explain the chemistry of transition metal elements; explain trends in oxidation states, through Latimer or Frost diagrams.'	12/05/2016
2	Amendment to second Evidence Requirement under Outcome 1 on page 4. 'Alkene' changed to 'alkane'.	12/05/2016
2	Amendment to final bullet point on page 6 to include the Cativa Acetic acid process as well as Monsanto process.	12/05/2016

General information for learners

Unit title: Applications of Transition Metal Compounds (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 Unit H939 35 *Transition Metal Chemistry: Theory and Laboratory Skills*, where you will have learned underpinning aspects of transition metal chemistry and developed your practical skills.

On completion of the Unit you should be able to:

1 Explain the role of inorganic compounds in catalytic, biochemical and pharmaceutical systems.
2 Perform practical experiments related to the role of transition metal compounds.

Outcome 1

In this Outcome, you will discuss the chemistry of specific transition metal elements. Different inorganic reaction types and their mechanisms will be covered, in particular you will look at oxidative addition reactions and their application in catalysis. You will also look at the role that transition metal elements have in a range of biological systems, eg haemoglobin, vitamin B12, etc and you will learn about the applications of transition metals in pharmaceuticals.

Outcome 2

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

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 Outcome 1 you will take a closed-book, end of Unit assessment.

Outcome 2 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 *Numeracy* and *Problem Solving* at SCQF level 6, and *Information and Communication Technology (ICT)* at SCQF level 4.