SQA Advanced Unit specification

General information for centres

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

Unit code: HV0M 47

Superclass: RD

Publication date: November 2017

Source: Scottish Qualifications Authority

Version: 01

Unit purpose

This Unit is designed to enable learners to understand key aspects of physical chemistry, encompassing gas behaviours, chemical kinetics, chemical thermodynamics and phase equilibrium. Learners will also develop practical skills in techniques relevant to physical chemistry. The Unit is suitable for learners studying at SQA Advanced Certificate level, and will provide the necessary underpinning knowledge and skills to enable progression to further study of physical chemistry at SQA Advanced Diploma 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 apply the principles, laws and formulae associated with gas behaviour.
2 Describe and apply the principles of chemical kinetics.
3 Describe and apply the principles of chemical thermodynamics.
4 Describe and apply the principles of phase equilibrium.
5 Perform practical experiments related to physical chemistry.

Credit points and level

1 SQA Credit at SCQF level 7: (8 SCQF credit points at 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 Unit HV00 47 *Fundamental Chemistry: Theory and Laboratory Skills* or equivalent.

Core Skills

Achievement of this Unit gives automatic certification of the following Core Skills component:

Complete Core Skill	None
Core Skill component	Using Number 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.

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**.

SQA Advanced Unit specification: Statement of standards

Unit title: Physical 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 apply the principles, laws and formulae associated with gas behaviour.

Knowledge and/or Skills

- Kinetic model of gases including Boltzmann distribution
- Gas laws including calculations
- Diffusion and/or effusion including calculations

Outcome 2

Describe and apply the principles of chemical kinetics.

Knowledge and/or Skills

- Factors affecting reaction rates in terms of collision theory: concentration, catalyst, temperature, pressure, surface area
- Order of reactions: 0, 1st, 2nd
- Reaction mechanisms
- Concept of Rate Determining Step in mechanisms

Outcome 3

Describe and apply the principles of chemical thermodynamics.

Knowledge and/or Skills

- First and second laws and concepts of thermodynamic quantities
- Calculations involving thermodynamic quantities
- Reaction spontaneity from thermodynamic calculations
- Calculations involving Hess's law

Outcome 4

Describe and apply the principles of phase equilibrium.

Knowledge and/or Skills

- Behaviour of one component systems in terms of phase diagrams
- Behaviour of two component systems in terms of phase diagrams
- Raoult's law in two component systems

Outcome 5

Perform practical experiments related to physical chemistry.

Knowledge and/or Skills

- Physical 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 1–4 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 5 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 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 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:

- Apply the kinetic model of gases including use of Boltzmann distributions.
- Describe gas laws; perform calculations, including the ideal gas law.
- Describe diffusion and/or effusion of gases; perform calculations involving comparative rates of diffusion and/or effusion.

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:

- Describe the effects and causes of factors affecting reaction rates in terms of collision theory: concentration, catalyst, temperature, pressure and surface area.
- Apply the concept of order of reactions: 0, 1st, 2nd.
- Apply the concept of reaction mechanisms.
- Apply the concept of Rate Determining Step in mechanisms.

Outcome 3

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:

- Describe and apply the first and second laws of thermodynamics; explain concepts of thermodynamic quantities.
- Perform calculations involving thermodynamic quantities.
- Predict the reaction spontaneity from thermodynamic calculations.
- Perform calculations involving Hess's law.

Outcome 4

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 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 the behaviour of one component systems in terms of phase diagrams.
- Describe the behaviour of two component systems in terms of phase diagrams.
- Apply Raoult's law to perform calculations on two component systems.

Outcome 5

Learners will perform a minimum of two practical experiments, the content of which will be related to two of the Outcomes 1–4. 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 physical 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 instructions and health and safety requirements.

Learners may report results either 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.

A minimum of one of the assessed practical experiments should require a graphical analysis of experimental data on the part of the learners.

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.

SQA Advanced Unit Support Notes

Unit title: Physical 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 part of the framework for the SQA Advanced Certificate/Diploma in Applied Sciences and the SQA Advanced Diploma in Applied Chemical Sciences but may be suitable for inclusion in other SQA Advanced science and engineering awards. It is designed to develop the theoretical and practical aspects of physical chemistry introduced in the Unit HV00 47 *Fundamental Chemistry: Theory and Laboratory Skills*.

Outcome 1 — Describe and apply the principles, laws and formulae associated with gas behaviour

Qualitative description of gas behaviour using kinetic model. Relation between kinetic energy and temperature, including application of Boltzman distributions.

Description of gas laws and calculations of gaseous properties using gas laws: Charles, Boyle, Guy-Lussac/Avogadro, Dalton, Ideal. Origin of non-ideal behaviour.

Principles of diffusion and effusion, and calculations of gases involving comparative rates of diffusion and effusion.

Outcome 2 — Describe and apply the principles of chemical kinetics

Qualitative description of the effects and causes of factors affecting reaction rate; concentration, catalyst, temperature, pressure and surface area.

Reaction order (0, 1st and 2nd) and examples of reaction mechanisms (eg SN1, SN2).

Consecutive step mechanisms and concept of Rate Determining Step in relation to experimental rate law.

Outcome 3 — Describe and apply the principles of chemical thermodynamics

Laws of thermodynamics (first and second). Forms of energy (heat, internal energy, enthalpy, work) and their inter-relationships.

Concept of entropy in terms of disorder of both movement and position. Entropy of phase and chemical changes.

Gibb's Free Energy and prediction of reaction spontaneity from thermodynamic calculations in terms of second law.

Application of Hess's law and construction of Born-Haber cycles to determine unknown enthalpy values (eg enthalpy of formation, lattice enthalpy).

Outcome 4 — Describe and apply the principles of phase equilibrium

Pressure/volume phase diagrams of one component systems. Effect of pressure on melting, boiling and sublimation points. Applications of phase diagrams.

Vapour pressure/mole fraction phase diagrams for two component systems. Application of Raoult's law to perform calculations. Origins and effects of non-ideal behaviour.

Outcome 5 — Perform practical experiments related to physical 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 1–4.

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 1–4 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 5 will be undertaken in a similar timeframe to the underpinning theory.

It is envisaged that delivery of Outcome 1 could commence with a qualitative overview of gas behaviour — including the kinetic model and Boltzmann distributions. The nature and application of the basic gas laws (Charles, Boyle, Guy-Lussac/Avogadro, and Dalton) could be covered first, leading on to the ideal gas law. Although application of the non-ideal gas law is beyond the scope of this Unit, learners should still be made aware of the reasons for deviation from ideality and the circumstances under which non-ideality would be significant. The concepts of diffusion and effusion can be explained in terms of the kinetic energies of gases, and comparative rates of diffusion/effusion of gases calculated in relation to molecular mass. A number of scientific and commercial applications of the gas laws may be deployed to enhance learner's awareness of the relevance of the gas laws, eg automobile air-bags, uranium enrichment, determination of absolute zero, diesel engines.

Outcome 2 is intended to build on learners' understanding of reaction kinetics and to familiarise them with key aspects of mechanisms and rate laws for potential further study at SCQF level 8.

It is envisaged that delivery could commence with an overview of generic potential energy profiles for chemical reactions, followed by qualitative considerations of factors affecting reaction rate in terms of PE profiles and activation energy. Aspects covered would be effect of reactant concentration; catalyst, temperature, pressure and surface area.

The concept of reaction order should be introduced, and learners should understand that there is no correlation between order and molecularity. Examples of reaction mechanisms (consecutive step) should be used to explain the origin of rate laws in terms of the concept of Rate Determining Step. The use of SN1 and SN2 mechanisms here will also provide a link to organic chemistry.

Outcome 2 is suitable for delivery in an experimental context with learners being introduced to a variety of approaches for monitoring reaction progress.

Delivery of Outcome 3 could commence with a consideration of the first law of thermodynamics. This should then be explained in terms of the relationships between different forms of energy (heat, internal energy, enthalpy, work). The application of a piston model would facilitate understanding of these relationships.

The concept of entropy would be introduced in terms of disorder of both movement and position. Modelling apparatus (eg random gas mixing) could be used to enhance understanding. The calculation of entropy of phase changes would be undertaken before progressing to consider Gibb's Free Energy and prediction of reaction spontaneity in terms of second law. The relationship between Free Energy and equilibrium constants should also be examined both mathematically and qualitatively in terms of direction of change.

Learners will also apply Hess's law and construct Born-Haber cycles to determine unknown enthalpy values (eg enthalpy of formation, lattice enthalpy).

Delivery of Outcome 4 could commence with a re-cap of pressure effects in relation to Le Chatelier's principle, followed by a consideration of changes in melting, boiling and sublimation points of pure substances under conditions of varying pressure. Learners should be able to construct one component pressure-temperature phase diagrams from experimental data, and should be able to use the diagrams to explain and predict changes in state. The anomalous phase diagram of water should be understood. Several applications of phase diagrams could be covered, eg dew point, ice-skating, boiling point at elevated altitude.

Two component phase diagrams (vapour pressure vs composition) should be covered both qualitatively and mathematically in terms of Raoult's law. Learners should be able to interpret and explain phase diagrams and perform calculations for ideal systems. The origins of non-ideal behaviour should be discussed qualitatively.

It is envisaged that Outcome 5 will be delivered alongside the theoretical based Outcomes 1–4. 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 gas laws (eg determination of absolute zero by Charles's Law extrapolation), gas diffusion rates by ammonia-hydrogen chloride reaction, kinetics measurements (eg iodine clock, iodination of propanone), Hess's law (eg enthalpy of neutralisation), free energy determination via equilibrium constant, investigation of fractional distillation vis a vis phase diagrams and elevation of boiling point/depression of freezing point.

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 1–4 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 1–4 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 5 learners are required to undertake two assessed practical experiments, the content of which will be related to two of the Outcomes 1–4. 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. A minimum of one of the assessed practical experiments should require a graphical analysis of experimental data on the part of the learners.

- Suitable practical experiments for Outcome 1 are:
  - Determination of absolute zero by extrapolation of Charles's Law.
  - Determination of molar volume of a gas by quantitative electrolysis.

- Suitable practical experiments for Outcome 2 are:
  - Kinetics of iodine/propanone reaction.
  - Effect of hydrogen ion concentration on bromate/bromide reaction.

- Suitable practical experiments for Outcome 3 are:
  - Determination of decomposition temperature of sodium hydrogen carbonate, and relation to thermodynamic parameters.
  - Determination of equilibrium constant (eg of a weak acid) and relation to free energy.
  - Experimental application of Hess's law.

- Suitable practical experiments for Outcome 4 are:
  - Determination of a partition coefficient.
  - Determination of molecular mass of acetanilide by Beckmann's cryometer.

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.

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

This Unit has the Using Number component of Numeracy embedded in it. This means that when learners achieve the Unit, their Core Skills profile will also be updated to show they have achieved Using Number at SCQF level 6.

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, 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. Learners will be required to reach sound conclusions on the basis of the data collected and the inherent errors.

Information and Communication Technology — 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

SQA acknowledges the valuable contribution that Scotland's colleges have made to the development of SQA Advanced Qualifications.

FURTHER INFORMATION: Call SQA's Customer Contact Centre on 44 (0) 141 500 5030 or 0345 279 1000. Alternatively, complete our Centre Feedback Form.

General information for learners

Unit title: Physical 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 SQA Advanced Certificate/Diploma science programme. Before progressing to this Unit it would be beneficial to have completed the Unit HV00 47 *Fundamental Chemistry: Theory and Laboratory Skills*, where you will have learned underpinning aspects of physical 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 apply the principles, laws and formulae associated with gas behaviour.
2 Describe and apply the principles of chemical kinetics.
3 Describe and apply the principles of chemical thermodynamics.
4 Describe and apply the principles of phase equilibrium.
5 Perform practical experiments related to physical chemistry.

Outcome 1

In this Outcome you will cover a general overview of gas behaviour — including the kinetic model and Boltzmann distributions. The nature and application of the basic gas laws (Charles, Boyle, Guy-Lussac/Avogadro, and Dalton) will be covered, leading on to the ideal gas law. The concepts of diffusion and effusion of gases will be explained, and you will learn how to perform calculations on comparative rates of diffusion/effusion of gases in relation to molecular mass. You will also learn about a number of commercial and scientific applications of the gas laws.

Outcome 2

In this Outcome you will cover essential aspects of reaction kinetics and you will become familiar with key aspects of mechanisms and rate law. An overview of generic potential energy profiles for chemical reactions, followed by considerations of factors affecting reaction rate in terms of PE profiles and activation energy, will provide you with a general introduction to the topic.

You will be introduced to the concepts of reaction order, reaction mechanisms and rate-determining steps, and you learn about the experimental methods which may be deployed to investigate reaction kinetics.

Outcome 3

In this Outcome you will focus on the applications of the first and second laws of thermodynamics, and the related thermodynamic quantities. The first law of thermodynamics will be explained, and the applications of the first law to real-life situations will be covered.

The concept of entropy (chemical disorder) will be explained. You will learn about the second law of thermodynamics, and how to apply this law to determine reaction spontaneity. You will also apply Hess's law and construct Born-Haber cycles to determine unknown enthalpy values (eg enthalpy of formation, lattice enthalpy, etc).

Outcome 4

In this Outcome you will learn about phase equilibria in one and two component systems. You will learn how to construct phase diagrams, and how to apply them to real-life and commercial situations.

Outcome 5

In this Outcome you will undertake two assessed practical experiments, the content of which will be related to two of the Outcomes above.

During this practical work, you will also be expected to 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 4 you will take a closed-book, end of Unit assessment.

Outcome 5 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

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.

This Unit has the Using Number component of Numeracy embedded in it. This means that when you achieve the Unit, your Core Skills profile will also be updated to show you have achieved Using Number at SCQF level 6.