Science standards

Grade 12

Foundation level

Summary of students' performance by the end of Grade 12

Scientific enquiry

Students identify, develop and make predictions related to a clearly focused research question. They control variables, work as a team and use appropriate equipment and materials. They evaluate experimental design, identify weaknesses and develop realistic strategies for improvement. They work in an ethical manner. They understand the historical development of major scientific ideas and know scientific work is affected by its context. They are aware of the power and limitations of science in addressing questions. They record and process raw data appropriately and draw valid conclusions, allowing for errors and uncertainties. They handle equipment competently with due regard for safety. They follow instructions accurately but are able to adapt to unforeseen circumstances.

Biology

Students describe the structural features of chloroplasts and how these relate to the chemical processes of photosynthesis. They know that ATP is the immediate energy source in cellular processes and relate this to photosynthesis. They outline the reaction steps in the light-dependent and light-independent stages of photosynthesis. They relate the structure of a plant leaf to its function in photosynthesis and understand the factors limiting the rate of photosynthesis. They understand the need for a transport system in multicellular plants. They recall the structure, function and distribution of phloem and xylem in the roots, stems and leaves of a dicotyledonous plant. They describe translocation and transpiration. They explain water movement between cells, and between cells and their environment, in terms of water potential. They know that organisms that can respond to changes in their environment have an increased chance of survival. They understand the principles of homeostasis and negative feedback. They compare and contrast the hormonal and nervous control systems. They describe mammalian thermoregulation and the oestrous cycle. They know that the body produces antibodies against antigens, and understand the causes and transmission of HIV/AIDS, its global significance and problems of control. They understand how genetic variation occurs through allele segregation and chromosome cross-overs. They understand how sex is determined in humans and the mechanism of sex linkage. They understand the difference between dominant and recessive alleles and calculate genotype and phenotype frequencies in monohybrid crosses. They understand that predation, disease and competition result in differential survival rates and reproduction, and that organisms with a selective advantage are more likely to survive and pass on genes to the next generation, that natural selection and isolation can lead to new species, and that evolution over a long period of time has given rise to the diversity of living organisms. They understand the basic principles of genetic engineering. They know how micro-organisms are used in the food industry and in the treatment of wastewater.

Chemistry

Students know that weak bonds caused by dipole attraction hold particles together and they know of hydrogen bonding and its consequences, describe dative bonding and know that compounds' physical properties depend on their bonding type. They solve problems using the mole, the Avogadro constant, molar solutions, molar gas volume and the universal gas equation. They know the properties of the common compounds of silicon, nitrogen, phosphorus, oxygen and sulfur, and the characteristic properties of the first-row transition elements. They recognise the relative unreactivity of the arene ring. They know the characteristic structures of addition and condensation polymers. They know how to make soaps from fats, and how soaps and detergents solubilise oily stains.

Physics

Students know that there are many interconvertible forms of energy and perform calculations using expressions for kinetic and potential energy, work and power. They know how heat is transferred and use the concepts of specific heat capacity and specific latent heat to calculate heat transferred to bodies. They know that energy is transferred in the form of waves and perform calculations involving velocity, frequency and wavelength. They explain refraction in terms of change in velocity of the wave and relate this to refractive index, and explain diffraction, superposition and constructive and destructive interference in terms of wave motion. They know that the electromagnetic spectrum consists of electromagnetic radiation of varying frequency but with the same velocity in a vacuum and describe the properties and applications of the main parts of the spectrum. Students know that the relative motion of a conductor in a magnetic field induces an e.m.f. in the conductor and know the factors that influence the magnitude and direction of the e.m.f. They describe the commercial production of AC, perform calculations related to its parameters, and know why and how transformers are used in its distribution. They describe a simple model for the nuclear atom and the evidence for it, and recognise that some nuclides are unstable and decompose to simpler ones, emitting three forms of radiation in the process. They characterise the three radiation forms and know some of their uses. They distinguish between nuclear fission and fusion and understand the dangers associated with them. They have an understanding of the properties of the electron and some of its main uses.

Assessment weightings for Grade 12 foundation level

There are three general assessment objectives for the science curriculum:

- knowledge and understanding;
- application of knowledge and understanding, analysis and evaluation of information;
- scientific enquiry skills and procedures.

The science standards for Grade 12, foundation level, are grouped into four strands: three subject content strands – biology, chemistry and physics – and the scientific enquiry skills strand, which addresses the development of scientific practical and intellectual skills across all the content strands. The teaching and the assessment of the scientific enquiry skills strand should be carried out as an integral part of the teaching of the content strands.

For Grade 12, foundation level, each of the three subject content strands – biology, chemistry and physics – carries an equal weighting.

For Grade 12, foundation level, the weightings of the assessment objectives to be applied to each content strand are as follows:

	Knowledge and understanding	Application, analysis and evaluation	Scientific enquiry skills and procedures
Assessment weighting	45 to 55%	25 to 35%	20 to 25%

Science standards

Grade 12

Foundation level

Scientific enquiry

Key standards

Key standards are shown in shaded rectangles, e.g. 1.3.

Examples of learning exercises

The examples of active learning exercises shown in italics are intended to be illustrative and do not represent the full range of possible exercises.

By the end of Grade 12, students identify, develop and make predictions related to a clearly focused research question. They control variables, work as a team and use appropriate equipment and materials. They evaluate experimental design, identify weaknesses and develop realistic strategies for improvement. They work in an ethical manner. They understand the historical development of major scientific ideas and know scientific work is affected by its context. They are aware of the power and limitations of science in addressing questions. They record and process raw data appropriately and draw valid conclusions, allowing for errors and uncertainties. They handle equipment competently with due regard for safety. They follow instructions accurately but are able to adapt to unforeseen circumstances.

Students should:

1 Use methods of scientific investigation

1.1 Identify and develop a clearly focused research question.

Investigate factors limiting the rate of photosynthesis.

Determine how wind speed influences the rate of transpiration of a leafy plant.

Determine the acceleration due to gravity using a pendulum (advanced) or a free-fall method.

Determine the percentage of a commercial baking powder that is sodium bicarbonate.

1.2 Make predictions directly related to a research question.

Predict the progeny of a genetic cross.

Use modelling to predict changes in population density in predator–prey relationships.

Predict the characteristic properties of an element (e.g. tin, nickel) from its position in the periodic table and suggest ways to test some of the predictions.

Test the prediction that anodising a sample of aluminium increases its resistance to corrosion.

1.3 Identify and control variables.

Investigate the rate of osmosis between solutions of different concentration.

Investigate the rate of photosynthesis of an algal culture at different light intensities.

Compare the behaviour of different materials under stress.

1.4 Work constructively and adaptively with others as a team on a scientific investigation.

Work as a team to investigate the inheritance of selected characteristics of fruit flies.

Work as a team to investigate and explain the incidence of colour blindness in a community.

1.5 Evaluate experimental design, identify weaknesses and develop realistic strategies for improvement.

Develop and evaluate an experimental design to track the impact of humans on an area of desert.

Design an experiment to measure the rate of translocation in a green plant.

Identify the main sources of error when determining g by a free-fall method.

Identify the sources of error in an experiment to measure the power output of a muscle system and develop strategies for dealing with them.

1.6 Work in an ethical manner with regard to acknowledging data sources and authenticity of results.

Use published literature to find out the amount of selected yeast-based products produced annually in Qatar and in some other countries.

Write an illustrated report on the structure and function of chloroplasts.

Make a picture display of areas of Qatar that have been affected by industrialisation to illustrate positive and negative impacts.

1.7 Work in an ethical manner with regard to living things and the environment.

Carry out a survey of the habitats on a rocky shore to determine human impact.

Study the inheritance of characteristics of mice.

1.8 Identify, and make critical use of, secondary information.

Request information on the amount of sewage processed by sewage works in different areas of Qatar and account for the data.

Search the Internet for examples of genetically modified plants and their usefulness.

Download information on the explosion at Chernobyl from various sources to cross-check their veracity.

2 Know how scientists work

2.1 Understand the historical development of major scientific ideas.

Make a video on the work of Mendel.

Research the development of theories of translocation.

Study the evolution of our ideas about the nature of light.

2.2 Know how scientific work is affected by its economic, social, cultural, moral and spiritual contexts.

Debate the cultural, ethical and moral constraints placed by societies on contentious scientific research (e.g. genetic manipulation and gene cloning).

Identify major scientific developments that have arisen from national needs (e.g. Germany's need for a local source of fertiliser in 1914, the 'space race' of the late twentieth century).

2.3 Show an understanding of the power and limitations of science in addressing industrial, social and environmental questions.

Make a list of ways in which science can help stem the HIV/AIDS pandemic and a second list of problems associated with HIV/AIDS that science cannot resolve.

Discuss the reasons why, although we understand the biochemistry of human reproduction, some areas of the world are overpopulated and have an increasing birth rate.

Debate issues around the deliberate and accidental release of harmful chemicals into the environment.

See Standard 18.5

3 Process and communicate information

3.1 Record raw data appropriately in a manner that allows easy interpretation.

Draw diagrams to illustrate the inheritance of alleles through generations.

Construct tables to describe the key characteristics of animals in different phyla.

Make large labelled diagrams of xylem and phloem cells.

3.2 Process raw data by the most appropriate means.

Graph data on the rate of photosynthesis in relation to temperature at different light intensities.

Collect data on people living with HIV/AIDS in different countries and present as percentages of population and as numbers per unit area of the country.

3.3 Draw valid conclusions, allowing for errors and uncertainties.

Rework the data on Mendel's experiments with peas and discuss the certainty of the conclusions.

Use a graphical method for determining g using a pendulum that allows errors to be spotted and eliminated.

3.4 Use an appropriate range of methods to communicate scientific information.

Use models to show mechanisms such as the structure of phloem and xylem.

Create a PowerPoint presentation about homeostasis.

Use applets to illustrate a variety of three-dimensional physical processes.

4 Handle equipment and make measurements

4.1 Select and use correctly and competently the appropriate equipment and materials for an investigation, with due regard for the safety of self and others.

Use an oxygen meter in the study of photosynthesis.

Use a potometer to investigate transpiration.

Use a razor blade to cut sections and make slides of plant stems and leaves.

Use a xenon stroboscope to determine the frequency of a vibration.

Use a laser and a microwave generator to show interference.

Use a spectroscope to study emission and absorption spectra.

4.2 Follow instructions accurately but be able to adapt to unforeseen circumstances.

Biology

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Students should:

5 Link biological structures to their functions

5.1 Describe the structure of chloroplasts and link this to the biochemical and photochemical reactions of photosynthesis.

Study electron microscope pictures of cell structures.

Make a model chloroplast.

Study prepared slides of cross-sections of leaf cells under the microscope.

5.2 Describe the structure of a dicotyledonous leaf and a palisade cell and relate their structures to their roles in photosynthesis.

Cut cross-sections of leaves, prepare slides, study with a microscope and draw.

Study and draw the morphology of a range of plant leaves.

Trace round some leaves from a plant and calculate their surface areas. Estimate the total surface area of all the leaves of the plant.

6 Know the stages in the biochemistry of photosynthesis

6.1 Describe the role of ATP as the universal energy currency in all living organisms and relate this to photosynthesis.

Study diagrams of biochemical pathways and identify reactions involving ATP.

6.2 Describe the reaction steps in the light-dependent and light-independent stages of photosynthesis, including the role of ATP.

Make cards showing the reaction steps of photosynthesis and arrange these to illustrate the light-dependent and light-independent stages.

Use the Internet to find out about the contribution of Calvin to our understanding of photosynthesis.

ICT opportunity

Use the Internet to gather information.

7 Understand the factors that limit the rate of photosynthesis

7.1 Explain how carbon dioxide concentration, light intensity and temperature are interdependent limiting factors for photosynthesis.

Investigate how the rate of photosynthesis of a culture of algae is affected by light intensity, carbon dioxide and temperature.

Measure the rate of oxygen bubbles produced by Elodea *when placed in different light intensities.*

ICT opportunity

Use dataloggers and probes.

8 Understand the transport systems in dicotyledonous plants

8.1 Explain why large plants need transport systems for gases, water and food in terms of their surface area to volume ratios.

Calculate the surface area to volume ratios of different-sized cubes.

Measure the rate of diffusion of a drop of coloured liquid in different volumes of water.

8.2 Describe the vascular systems of the roots, stems and leaves of dicotyledonous plants and relate the structure and distribution of xylem and phloem to their functions.

Cut longitudinal and transverse sections of roots, stems and leaves, and examine with a microscope.

Examine cut sections of a tree trunk or branch.

Make a model root and stem to show the vascular bundles.

8.3 Explain the movement of water between plant cells, and between plant cells and their environment, in terms of water potential.

Make model cells from visking tubing. Fill one cell with water and put different concentrations of sugar solution in the other cells. Place the cells so that the water cell is touching all the others. Leave for some time and look for signs of movement of water into the various cells.

Examine some plant cells under the microscope. Add water to the cells and re-examine. Then add sugar solution and examine again.

8.4 Describe the processes of translocation of photosynthetic products in the phloem and transpiration of water and dissolved miners in the xylem.

Tie a polythene bag over some leaves of a healthy plant. Look for signs of water loss by the leaves.

Use a potometer to investigate water loss by leaves.

9 Understand physiological regulatory systems of mammals

9.1 Explain the importance to the survival of organisms of being able to respond to environmental stimuli.

Watch a wildlife video that illustrates a range of ways in which animals detect potential dangers.

ICT opportunity
Use video for illustration.

9.2 Explain the importance of homeostasis in mammals and describe the process in terms of receptors, effectors and negative feedback.

Construct charts to compare mammalian feedback mechanisms with mechanical and electrical regulatory systems.

9.3 Describe thermoregulation in humans and the roles of TRH and TSH.

Watch and discuss a video about human survival in hot and cold conditions.

ICT opportunity
Use video for illustration.

Write a play about survival in hot and cold conditions.

9.4 Describe the mammalian oestrous cycle and the roles of oestrogen, progesterone, LH and FSH.

Study and interpret data on the hormone levels in the blood system of women over a monthly cycle and when pregnant.

Use the library and the Internet to find out about the hormonal action of female contraceptive pills.

ICT opportunity
Use the Internet to gather information.

9.5 Describe the similarities and differences between nervous and hormonal control systems in mammals.

Give groups of students a set of cards that state properties of the hormonal and nervous systems. Ask them to sort the cards into sets of properties that are unique to each system and properties that are common to both systems.

10 Understand the HIV/AIDS pandemic

10.1 Explain the causes and transmission mechanisms of HIV/AIDS, how its spread may be controlled and the significance of the pandemic.

Collect data from the Internet and plot the estimates of people living with HIV/AIDS in various countries against time; discuss possible reasons for differences and changes.

ICT opportunity
Use the Internet to gather information.

Find out if there are any available HIV/AIDS statistics for Qatar and if these show any trend.

10.2 Explain the action of antibodies against antigens in the human immune system.

Make a diagrammatic model of an antibody–antigen reaction.

Survey the class to determine how many students suffer from hay fever.

11 Understand genetic inheritance

11.1 Explain the terms *gene*, *allele*, *phenotype*, *genotype*, *dominant*, *recessive* and *co-dominant*.

Construct a quiz in which teams of students write correct and incorrect definitions of terms and ask other teams to select the correct one.

11.2 Use genetic diagrams to solve genetic problems involving monohybrid crosses.

Using fruit flies or other organisms to track the pattern of inheritance of characteristics.

Predict and check the progeny of genetic crosses.

11.3 Explain how variation occurs through segregation of alleles during gamete formation and through the crossing over of chromosome segments during meiosis.

Using coloured beads as alleles, follow the pattern of their segregation during gamete formation and possible combinations in fertilisation.

Use a microscope to study prepared slides of chromosome cross-overs.

11.4 Know how X and Y chromosomes determine sex in humans and the inheritance pattern of sex-linked characteristics.

Make model X and Y chromosomes and track their segregation during gamete formation and possible combinations in fertilisation.

Use a microscope to study prepared slides of human X and Y chromosomes.

Predict and check the progeny of parents carrying the colour-blind allele.

12 Know the mechanism and outcomes of natural selection

12.1 Know that predation, disease and competition within a population results in the survival and reproduction of the strongest individuals and that this natural selection allows the inheritance of their characteristics.

Use the library to find out about the work of Darwin and Wallace.

12.2 Know that natural selection and breeding isolation can lead to speciation.

Watch and discuss video material on evidence and argument in support of and counter to the theory of evolution by natural selection.

ICT opportunity

Use video for information.

Find out why the Galapagos islands are of interest to those studying evolution.

12.3 Explain how natural selection and evolution over a long period of time have resulted in a great diversity of forms among living organisms.

Hold a class debate in which teams put forward scientific evidence for and against the theory of evolution by natural selection.

12.4 Give examples and explanations of how organisms are adapted to survive in particular environmental conditions.

Match pictures of organisms with descriptions of their adaptations for living in their natural habitat.

13 Understand the basis of biotechnology

13.1 Explain the principles of gene cloning and the roles of restriction enzymes, recombinant DNA, plasmids and bacteriophages.

Using coloured Plasticine or string, simulate the processes involved in gene cloning.

Make a collection of press cuttings about genetic engineering. Discuss the correctness of the science described in each report and the consequent appropriateness of the article.

13.2 Explain some of the potential advantages of, and ethical and moral concerns about, genetic engineering.

Interview people about their views on genetic engineering. Use the interviews to inform a class debate on the subject.

Write an article arguing for the use of generic engineering to help create useful organisms and then write a second article arguing why it is wrong to do so.

13.3 Explain some uses of micro-organisms in food production.

Survey food shops to discover products made with the aid of micro-organisms.

Compare the time taken for milk to turn sour when kept in different conditions.

Mix flour dough with different amounts of yeast and sugar and measure the time taken for the dough to rise to a predetermined size.

13.4 Explain how micro-organisms are used in the treatment of wastewater.

Visit a wastewater treatment plant.

Chemistry

By the end of Grade 12, students know that weak bonds caused by dipole attraction hold particles together and they know of hydrogen bonding and its consequences, describe dative bonding and know that compounds' physical properties depend on their bonding type. They solve problems using the mole, the Avogadro constant, molar solutions, molar gas volume and the universal gas equation. They know the properties of the common compounds of silicon, nitrogen, phosphorus, oxygen and sulfur, and the characteristic properties of the first-row transition elements. They recognise the relative unreactivity of the arene ring. They know the characteristic structures of addition and condensation polymers. They know how to make soaps from fats, and how soaps and detergents solubilise oily stains.

Students should:

14 Understand the structures of atoms and molecules, and know how these determine their physical and chemical properties

14.1 Know that permanent and induced molecular dipoles can give rise to intermolecular forces (van der Waals' forces), and explain their consequences in terms of physical properties of elements and compounds.

Make a list or display of elements and compounds that have anomalous physical properties that can be ascribed to van der Waals' forces (e.g. $CHCl_3(l)$, $Br_2(l)$ and the liquid noble gases).

14.2 Describe hydrogen bonding, using ammonia and water as simple examples of molecules containing N–H and O–H groups.

Compare graphically the physical properties of similar compounds (e.g. the group V, VI and VII hydrides) to show the influence of hydrogen bonding.

14.3 Know the importance of hydrogen bonding to the physical properties of substances, particularly ice and water, and to the structures of important organic molecules such as proteins and nucleic acids.

Discuss, and demonstrate using models, the importance of hydrogen bonding in the base pairing of DNA and RNA and in the three-dimensional structure of proteins such as haemoglobin.

14.4 Explain the shapes of simple covalent molecules in terms of electron-pair repulsion (including lone pairs) and know how molecular shape can give rise to permanent dipoles.

Attract a stream of slowly flowing tap water to a charged ruler and explain the phenomenon in terms of the shape of the molecule.

Make three-dimensional models using examples such as BF_3 (trigonal), CO_2 (linear), CH_4 (tetrahedral), NH_3 (pyramidal) and H_2O (non-linear).

14.5 Describe coordinate (dative covalent) bonding, as exemplified by the formation of the ammonium and hydroxonium ions and in the structure of carbon monoxide.

Draw Lewis 'dot and cross' diagrams to show coordinate bonding.

14.6 Account for the differences in physical properties of substances by reference to different types of bonding: ionic bonding; covalent bonding; hydrogen bonding; other intermolecular interactions; metallic bonding.

Investigate the physical properties of a variety of common substances with different bonding types.

ICT opportunity

Obtain physical properties from the Internet.

14.7 Describe, in simple terms, the differences between the lattice structures of crystalline solids which are: ionic, as in sodium chloride; simple molecular, as in iodine; giant molecular, as in graphite, diamond or silicon(IV) oxide; hydrogen bonded, as in ice; metallic, as in copper.

Download from the Internet Java applets showing these structures in rotatable three-dimensional diagrams. Study these compounds in the classroom to discover the macro-differences in their physical properties.

ICT opportunity

Use Java applets to show physical processes.

14.8 Describe the number and relative energies of the s, p, d and f orbitals for the principal quantum numbers 1, 2, 3 and 4, and show how this leads to the structure of the periodic table.

Draw an energy-level diagram showing the levels of the s, p, d and f orbitals for the principal quantum numbers 1 to 4.

14.9 Describe the shape of the s and p orbitals and their hybrids in atoms such as carbon and oxygen.

Make models or download Java applets showing the shapes of s and p hybrid orbitals.

ICT opportunity

Use Java applets to show orbital shapes.

14.10 Describe covalent bonding in terms of orbital overlap, giving σ (sigma) and π (pi) bonds; explain bond shape and angles in ethane, ethene and benzene in terms of σ and π bonds.

Make models or download Java applets, of simple compounds with π bonds to show molecular shape and areas of high electron probability.

14.11 Explain the lack of reactivity of the triple bond (as in nitrogen) in terms of bonding theory.

15 Understand the principles of stoichiometry

15.1 Write balanced equations and use them to provide information on reacting masses.

Demonstrate quantitatively the conservation of mass during a reaction using the burning of magnesium in a crucible.

15.2 Define a *mole* of a substance in terms of the Avogadro constant and use it in stoichiometric calculations.

Solve simple stoichiometric problems using familiar equations.

15.3 Calculate empirical and molecular formulae using combustion data or composition by mass.

Use data from the combustion of magnesium to show composition by mass.

15.4 Determine concentrations of reactants in solutions through acid–base titrations with appropriate indicators.

Perform simple acid–base titrations using appropriate indictors.

Solve percentage purity problems (e.g. the percentage of sodium bicarbonate in baking powder).

15.5 Apply the kinetic particle model to an ideal gas and explain, in terms of molecular size and intermolecular forces, how the behaviour of real gases deviates from the ideal model at high pressures and low temperatures.

15.6 Define *molar volume* and use it in calculations on the reacting volumes of ideal gases.

Demonstrate the concept of molar volume by measuring the gas evolved during an acid/carbonate reaction with a known quantity of reactant.

Apply the concept of molar volume calculation to real situations (e.g. the operation of a fire extinguisher).

15.7 Use the general gas equation $PV = nRT$ and the concept of relative molar volume at STP in calculations related to ideal gases.

Determination of Boyle's and Charles's laws. Extrapolate the Charles law result to show the absolute zero of temperature.

Carry out realistic calculations (e.g. bubble size in deep water, the volume of gas in weather balloons) using the gas laws to predict volume changes with changes in temperature and pressure.

ICT opportunity

Use electronic sensors to measure variables.

16 Know some properties of common group IV, V and VI elements and their compounds

16.1 Know the main properties and uses of oxygen, and the test for it.

Demonstrate the properties of pure oxygen in supporting combustion and test the product of the combustion of an element, if soluble, for acidity.

Generate oxygen on a small scale by heating potassium manganate(VII) and test for it.

Safety

Use of oxygen from a cylinder must only be done by the teacher.

16.2 Know that water is compound of hydrogen and oxygen.

Electrolyse water at platinum electrodes and collect and test the products.

16.3 Show an understanding of the properties of hydrogen peroxide as an acid and an oxidising agent and understand the use of peroxides as oxidants in rockets and explosives.

Investigate the decomposition of hydrogen peroxide using catalysts such as manganese dioxide. Investigate the bleaching action of dilute hydrogen peroxide on cloth and hair.

Explain the properties of hydrogen peroxide and other peroxides in terms of their structure.

Safety

Hydrogen peroxide can cause burns. Class experiments should use '5 volume' or less.

16.4 Know that ozone is a form of oxygen formed when oxygen is subjected to electrostatic discharges or high-energy radiation and that it is a powerful oxidising agent.

16.5 Know the physiological effects of ozone and recognise that in the lower atmosphere it is a pollutant but that in the upper atmosphere it protects living materials from destructive high-energy radiation.

Identify the presence of ozone around a photocopier by its characteristic acrid smell.

Recall the work done on the ozone layer in Grade 10.

16.6 Compare the physical and chemical properties of sulfur and oxygen and their simple compounds, such as their hydrides.

Compare the physical and chemical properties of the hydrides of sulfur and oxygen, noting the importance of hydrogen bonding in water and that hydrogen sulfide displays the properties of a weak acid. Compare the properties of selected oxides and sulfides, noting particularly the displacement of hydrogen sulfide by the reaction between sulfides and acids.

16.7 Know and explain the existence of two oxidation states of sulfur in its common compounds, as typified by its two common oxides and the two acids and series of salts that they form.

Prepare sulfur dioxide by burning sulfur, dissolve it in water and test the solution.

Demonstrate the preparation of sulfur trioxide crystals by the contact process using platinised mineral wool as catalyst.

Safety

Sulfur dioxide should be prepared in very small quantities in a well-ventilated room. Sulfur trioxide should be prepared in a fume cupboard.

16.8 Know the importance of sulfur dioxide in the preparation of sulfuric acid and in food preservation.

16.9 Know the role of sulfur dioxide in the formation of acid rain and describe the main environmental consequences of acid rain.

Investigate the effect of sulfur dioxide on plants growing in a closed container.

16.10 Know that nitrogen is an unreactive gas but that it can form nitrides with reactive metals.

Burn magnesium in nitrogen, dissolve the product in water and test the solution for alkalinity and the presence of the ammonium ion.

Find information about the effect of lightning on the air and the resultant production of nitrate.

16.11 Know the test for ammonia, the main properties and uses of its compounds and their reaction with warm alkali.

Investigate the reaction of ammonia or ammonia solution with reagents such as hydrochloric acid and copper salts, and the action of alkali and heat on ammonium salts.

Demonstrate the fountain experiment using ammonia to illustrate its solubility in water.

Show, using Lewis diagrams, the structure of the ammonium ion and how it is formed.

16.12 Know the main properties and uses of nitrates and understand their environmental impact.

ICT opportunity

Obtain current information from the Internet.

Obtain data on the world production and use of nitrogen fertilisers from the Internet and make graphical displays showing changes over time and by continent.

16.13 Know why nitrogen and phosphorus exhibit two common oxidation states in their compounds and how this leads to two series of compounds.

Investigate the properties of the oxides of nitrogen and phosphorus.

16.14 Recognise the importance of nitrogen and phosphorus to living things.

Study the structure and function of some key organic molecules (e.g. amino acids; nucleic acids) to show the importance of nitrogen and phosphorus.

16.15 Compare and contrast the physical and (inorganic) chemical properties of the group IV elements carbon and silicon and their properties.

Study the similarities and differences in the physical and chemical properties of the oxides of carbon and silicon, particularly their reaction with alkali.

Compare the reaction of solutions of sodium carbonate and sodium silicate with acid.

16.16 Know the industrial importance of silicon and the requirement in many applications that it should be extremely pure.

Study the process of zone refining to obtain impurity levels of less than one part in 10^{12}.

17 Know some properties of transition elements and their compounds

17.1 Know that transition elements typically form more than one stable ion and that they have generally similar physical and chemical properties.

Compare iron(II) and iron(III) salts with the same anion. Compare the colour of the salts and prepare the hydroxide from them. Account for the slow change of colour of iron(II) hydroxide on exposure to air.

Compare the colour and chemical and physical properties of salts containing manganese(II), manganese(III) and manganese(VII).

17.2 Know the electronic configurations and the typical properties of the first-row transition elements.

Compare the physical and chemical properties of common elements and their oxides, hydroxides, sulfates, chlorides and nitrates.

17.3 State some common uses of some transition elements, including examples of catalysis by transition metals, and relate these uses to their properties.

Make a display of the main properties of the transition elements, including their most significant alloys (such as steel).

Study the use of d-block elements and their compounds as catalysts in processes such as the contact process (vanadium(V)oxide), the Haber process (iron) and the preparation of margarine (nickel), and processes that are carried out in Qatar.

List a number of important industrial processes that involve transition metals or their compounds as catalysts. Include, particularly, processes carried out in Qatar.

17.4 Know that transition metals can form one or more stable ions through the involvement of electrons from the inner (d) orbitals and know that this results in multiple oxidation states.

Investigate the variation in oxidation state and colour of elements such as vanadium, chromium, manganese and iron through a variety of redox reactions.

18 Understand basic aromatic organic chemistry

18.1 Interpret and use the nomenclature and structural formulae of the following classes of compound:

- arenes;
- halogenoarenes;
- phenols.

18.2 Describe the chemistry of arenes (such as benzene and methylbenzene) and show an understanding of the relative unreactivity of the aromatic ring compared with an isolated double bond; know that the chemistry of side chains is similar to that of aliphatic compounds.

Safety

Benzene is carcinogenic.

Compare the reactions of benzene and of methylbenzene with hot dilute potassium manganate(VII) solution.

Compare the properties of benzoic and ethanoic acids, and (advanced) of benzaldehyde with ethanal.

18.3 Know the chemistry of phenol, as exemplified by its reactions with bases and sodium, and know of its common use as a mild disinfectant.

Compare the physical and chemical properties of phenol and ethanol.

18.4 Compare the preparation and properties of bromobenzene with bromoethane to show the effect of the benzene ring.

Prepare bromobenzene and show that it is largely unreactive towards the reagents that react readily with bromoethane.

18.5 Show an understanding of the broad issues relating to social benefits and environmental costs associated with the organic chemical industry.

Study the social benefits brought by the simple drug aspirin (acetylsalycilic acid) since its discovery over a century ago.

Study the consequences of the explosion in the Union Carbide factory at Bhopal, India.

Study issues raised by the release into the environment of potentially harmful chemicals such as DDT, polychlorinated biphenyls and certain chlorofluorocarbon refrigerants.

See Standard 2.3

All examples.

19 Understand the chemistry of some macromolecules

19.1 Know that a polymer is a macromolecule containing repeating units and recognise the difference between condensation and addition polymers.

Tabulate examples of natural and synthetic addition and condensation polymers, showing the monomers from which they are made and also their uses or natural functions. Note the importance of catalysts in making addition polymers.

19.2 Describe the manufacture and uses of synthetic addition polymers as exemplified by polythene and PVC, and of condensation polymers such as nylon and polyesters.

Make nylon from 1,6-diamino hexane and adipoyl chloride.

Make a study of the polymer industry of Qatar.

19.3 Know that living things produce many natural condensation polymers, such as proteins from amino acids, starch and cellulose from glucose, and DNA from nucleic acids.

Examine models and three-dimensional diagrams of naturally occurring polymers, noting the structural features that are related to their function.

19.4 Know that fats and oils are natural esters formed by the alcohol glycerol with long-chain fatty acids, and understand the meaning of the term *unsaturated* when applied to these esters.

Study the alleged advantages of a diet 'low in unsaturates'.

Make soap by hydrolysing castor oil (or any animal fat or vegetable oil).

19.5 Show how the typical structural features of soaps and detergents can explain how they can readily solubilise oily stains.

Draw a diagram (or download an applet from the Internet) to show how the characteristic structure of soaps and detergents, which are hydrophilic at one end and hydrophobic at the other, can solubilise an oil drop.

Physics

By the end of Grade 12, students know that there are many interconvertible forms of energy and perform calculations using expressions for kinetic and potential energy, work and power. They know that energy is transferred in the form of waves and perform calculations involving velocity, frequency and wavelength. They explain refraction in terms of change in velocity of the wave and relate this to refractive index, and explain diffraction, superposition and constructive and destructive interference in terms of wave motion. They know that the electromagnetic spectrum consists of electromagnetic radiation of varying frequency but with the same velocity in a vacuum and describe the properties and applications of the main parts of the spectrum. Students know that the relative motion of a conductor in a magnetic field induces an e.m.f. in the conductor and know the factors that influence the magnitude and direction of the e.m.f. They describe the commercial production of AC, perform calculations related to its parameters, and know why and how transformers are used in its distribution. They describe a simple model for the nuclear atom and the evidence for it, and recognise that some nuclides are unstable and decompose to simpler ones, emitting three forms of radiation in the process. They characterise the three radiation forms and know some of their uses. They distinguish between nuclear fission and fusion and understand the dangers associated with them. They have an understanding of the properties of the electron and some of its main uses.

Students should:

20 Understand the relationship between work, energy and power

20.1 Define work and apply the concept of work as the product of a force and displacement in the direction of the force.

Calculate the work done in simple situations (e.g. lifting a mass). This can be done as a class activity and a spreadsheet can be used to process all the results.

(Advanced) Use a force–displacement graph to determine the work done on a body when the force on it is not constant.

ICT opportunity

Use a spreadsheet to process large numbers of results.

20.2 Define kinetic and potential energy. Give examples of different forms of energy and their interconversion by transducers of various kinds, and classify them as potential or kinetic. Describe the principle of energy conservation and apply it to simple examples.

Draw flow charts showing the energy inputs and outputs of some everyday energy transducers. Give some idea of the relative proportions of the different forms of energy produced (e.g. by using arrows of different widths).

20.3 Recall, derive and apply the formulae $E_k = \frac{1}{2}mv^2$ and $E_p = mgh$.

Study falling objects in air or a fluid using a video camera and calculate the velocity just before impact. Compare the gain in kinetic energy with the loss in potential and account for any difference.

ICT opportunity

Use video or multiflash photography.

20.4 Know that in practical systems energy loss, particularly in the form of waste heat, always occurs and use the concept of efficiency to solve problems. Calculate conversion efficiencies relating energy input to useful energy output.

Measure or calculate energy inputs and useful energy outputs in everyday transducers (e.g. a motor vehicle).

Study ways in which production of waste heat is minimised, or is used or dispersed in Qatar industrial plants such as the power stations.

20.5 Define power as the rate of doing work or converting energy and solve problems using $P = W/t$.

Take appropriate measurements to calculate the power output of a muscle system (e.g. a leg or an arm). Compare maximum output with maximum sustained output.

21 Understand the properties of waves

21.1 Know what happens to waves when they are reflected and refracted; explain diffraction, superposition and constructive and destructive interference in terms of wave motion.

Study diffraction, refraction and interference of waves using a ripple tank.

Study the superposition of coherent sound waves from two identical loudspeakers.

Download a physics applet to show how interference depends on parameters such as slit width and distance apart.

ICT opportunity

Use Java applets to show scientific principles.

Study diffraction and interference of light using a laser and two slits, and of microwaves using a microwave generator, slits and detector.

Safety

Follow safety guidelines when using lasers.

(Advanced) Demonstrate and explain the phenomenon of 'beats' when sound waves interfere, using two strings or pipes tuned to almost the same frequency.

(Advanced) Measure the velocity of sound using an interference method.

21.2 Explain refraction of light and water waves in terms of waves, know that the velocity of waves changes during refraction and relate this to refractive index.

Measure the refractive index of a variety of media and use it to calculate the velocity of light in each.

21.3 Use a diffraction grating to show diffraction and the production of visible spectra and to solve problems relating to interference phenomena using the relationships $\lambda = ax/D$ and $d \sin\theta = n\lambda$.

Use a diffraction grating with a white light source to measure the wavelength of different parts of the light spectrum.

Use an infrared detector when studying the diffraction of white light to show that heat radiation is diffracted beyond the red light.

Show and explain how a light source can give rise to interference patterns when light is reflected from both sides of a parallel thin film (e.g. oil on water).

21.4 Explain the Doppler effect in terms of wave motion and give examples from sound and light.

Record the Doppler effect generated by a fast-moving car blowing its horn. Analyse the sound using an oscilloscope to determine the speed of the car.

Discuss the mechanism and use for radar speed traps.

21.5 Explain the phenomena of coherence and polarisation of transverse waves and describe applications of both.

Study the effect of crossed Polaroid sheets on the transmission of light.

Demonstrate the polarisation of microwaves by rotating the microwave diffraction grating.

Demonstrate the polarisation of light scattered on passing through slightly cloudy water.

Show and explain the phenomenon of double refraction by Iceland spar crystals.

Study the mechanism of transmission of digital information in fibre-optic cables, and of the mechanism behind a liquid crystal display.

21.6 Explain electromagnetic radiation in terms of oscillating electric and magnetic fields and know that all electromagnetic waves travel with the same velocity in free space. Describe the main characteristics and applications of the different parts of the electromagnetic spectrum and give examples of the reflection, refraction and interference of electromagnetic waves.

Demonstrate ultraviolet and infrared radiation at the extremes of a visible spectrum using appropriate detectors.

Study reflection, refraction and interference of light and microwaves.

Make a diagram or display showing the velocity and frequency range of different parts of the electromagnetic spectrum and the uses we make of each part.

Make a table of calculation results showing how long light takes to get to us from different light sources (e.g. a television set, a distant streetlight, the Moon, the Sun, a nearby star, the Andromeda galaxy – our nearest neighbour galaxy).

22 Understand electromagnetic induction

22.1 Describe the production of an induced e.m.f. by the relative motion between a conductor and a magnetic field and know the factors that influence the magnitude of the e.m.f.

Show, using an oscilloscope, an induced e.m.f. in a single coil moving in a magnetic field.

Show, using an oscilloscope, an induced e.m.f. in a solenoid when a magnet oscillates in and out of it.

22.2 Understand the concepts of magnetic flux and flux linkage and use Faraday's and Lenz's laws to solve numerical problems related to electromagnetic induction.

Mathematics

An understanding of calculus is required for an adequate treatment of this standard.

Demonstrate electromagnetic induction in a wire moving through a magnetic field.

Vary parameters (e.g. number of coils, rapidity of movement) when studying induced e.m.f.s.

22.3 Describe how eddy currents form and know some of the applications of eddy currents, such as zone refining of semiconductors.

Show the formation of eddy currents in q freely suspended aluminium sheet between the poles of an AC electromagnet. Show how an aluminium grid similarly suspended will fail to move.

Construct an electromagnetically damped pendulum.

Demonstrate the importance of a laminated core in a transformer.

Make an induction motor.

22.4 Know that alternating current is induced in a coil rotating in a uniform magnetic field and explain the operation of a simple AC generator.

Make and test a simple generator.

22.5 Describe the commercial production of alternating current using a gas turbine as the primary source of kinetic energy.

Visit Doha power station and develop an ICT display based on the visit. Include in the display any environmental issues and how they are dealt with.

22.6 Describe and use the concepts of *root mean square current* and *voltage*, *period*, *frequency* and *peak value* applied to alternating current; solve numerical problems related to them.

22.7 Describe the action of a transformer and explain its importance in the long-distance transmission of electricity; solve problems related to power transmission.

Make a model power transmission system and measure input and output for different transmission voltages.

Use a demountable transformer to demonstrate the structure and uses of transformers.

23 Understand the foundations of modern atomic and nuclear physics

23.1 Interpret the results of Rutherford's scattering experiment and describe how it led to modern models of the structure of the atom.

Study the different models for explaining the structure of matter that have evolved over time and also the reasons why earlier models have been superseded by subsequent ones.

See Standard 2.3

23.2 Describe a simple model for the nuclear atom in terms of protons, neutrons and electrons, use the common notation for representing nuclides and write equations representing nuclear transformations.

23.3 Understand the spontaneous and random nature of nuclear decay, interpret decay data in terms of half-life and explain the source of the background radiation.

Compare the background radiation over time and in different places of the school compound and elsewhere.

Model the decay process by repeatedly dropping a large number of drawing pins, removing all those that drop on their backs at each stage.

Measure the half-life of a short-lived isotope.

(Advanced) Determine the decay constant for the short-lived isotope.

Radioactivity

Radioactivity experiments must only be directed by teachers who have had appropriate training.

23.4 Know the properties of α-, β- and γ-radiations, including the dangers to life and health.

Demonstrate the ability of different materials to absorb the three kinds of radiation.

Show the effect of a magnetic field on β-radiation.

Demonstrate α- and β-radiation using a cloud chamber.

23.5 Know some common uses of radioisotopes.

Demonstrate the use α-radiation in a simple fire alarm.

List the uses made of radioisotopes in industry, in scientific research, in medicine and in the home. Note the class of radiation exploited in each case.

23.6 Know the source of energy in stars, including the Sun.

23.7 Distinguish between nuclear fission and nuclear fusion, and know how heavier elements are formed in older stars by nuclear fusion.

Write isotopic equations showing the formation of common elements and show why the common isotopes of the common elements up to iron-56 have a mass number that is divisible by 4.

23.8 Understand that while nuclear fission can be used peacefully as a source of energy, there are significant social, political and environmental dimensions to its use.

Draw a flow chart showing the processes involved in generating electricity from fissile materials.

Study videos and other materials related to the Chernobyl explosion and its aftermath.

Discuss topical issues related to nuclear fission (e.g. the advantages and disadvantages of nuclear power generation).

ICT opportunity

Using the Internet as an information source.

23.9 Show an understanding of the properties of the electron and the operation of the cathode-ray tube and the television tube.

Demonstrate the properties of an electron beam using a Maltese-cross tube.

Demonstrate the type of charge on an electron by connecting the target of a Perrin tube to an electroscope.

(Advanced) Study the historical development of our understanding of the nature of the electron, including the work of Crookes and Hertz, and the evidence that the electron is both a wave and a particle.