Are you ready for S285?

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1. Introduction

If you are intending to study S285, you will want to make sure that you have the necessary background knowledge and skills to be able to enjoy the module fully and to give yourself the best possible chance of completing it successfully. This booklet is intended to help you find out whether or not you are ready for S285.

Please read through these notes carefully, and work through the self- assessment questions (SAQs). You should allow yourself about an hour. This exercise will be useful for all prospective students of S285, even for those of you who have already studied other OU science modules and have completed the suggested prior study: working through these notes will serve as a reminder of some of the relevant facts, skills and concepts that you should be bringing with you from earlier study.

You shouldn't expect to be able to answer all the SAQs correctly now, but attempting them should allow you to judge (a) whether the module will interest you, (b) the areas where some reading beforehand would be useful and (c) whether you will be able to cope with the intellectual demands of the module. If you find these questions difficult to understand or answer, this does *not* mean you should not attempt S285, but suggests that you might find it helpful to do some preparatory work around the academic material in the module and to review your basic study skills. To help you do this, the S285 module team has compiled a primer containing some useful reference materials that you can access through the S285 module website.

If, after working through these notes, you are still unsure about whether or not S285 is the right module for you, we advise you to seek further help and advice from the Student Support Team (SST) for Undergraduate Science. Contact details for the SST can be found on StudentHome.

2. Module Profile

S285 is a multidisciplinary 30-credit Level 2 module that explores investigative approaches in biology and chemistry. The study of this module provides a solid foundation on which to build a life science or chemistry specialism. S285 is a compulsory module in R59 BSc (Hons) in Chemistry and an optional module for R58 BSc (Hons) in Biology and Q64 BSc (Hons) Natural Sciences.

The module is completely online comprising text, interactive media, audio-visual, collaborative and independent activities. No residential schools or face-to-face practicals are required for a succesful completion. S285 focuses at the theoretical and practical aspects of a range of techniques applied to research questions in biology and chemistry. Through the module you will be actively engaged with home, remote and online experiments. Students in S285 are expected to develop:

- Investigative skills through a series of multidisciplinary topics and practical investigations (separation science, food safety, pesticides and drug metabolism)

- Communication skills
- Numeracy
- Problem-solving skills
- Collaborative skills

S285 is an intensive 30 credit module and it is estimated it should require around 10 hours of study per week over the 30 weeks of the presentation. At Level 2 the depth of knowledge expected is greater than at Level 1 and studying can be significantly more demanding, at times seeming to take longer than the suggested number of hours.

You can find advice about planning your study time and time management within the 'Study Skills' section in StudentHome. If you would like additional advice about workload, please contact your Student Support Team, details for which can be found on StudentHome.

In order to do well in the assignments (TMAs) and end-of-module assessment (EMA) in this module, you will need:

- The ability to write concisely in order to answer factual or evaluative questions, or summarize a piece of text in your own words.
- The ability to organize and present material in a logical progression of linked points in a clear and concise manner to produce longer written reports.
- A basic mathematical competence and ability to extract information from data and statistics presented in various formats (such as tables, graphs and bar charts). In addition, a basic familiarity with standard units of measurement (SI units) is needed.
- The ability to analyse and interpret information from a range of sources.
  Confident IT skills so that you can follow module guidance to complete online experiments and database activities, use word processing and other software to prepare your assignments for online submission. Note that you do not have to have done these things before, and you are not expected to already know how to do them. Guidance is provided within the module, and support will be available from a tutor.

3. Suggested prior study

Before starting this module, we strongly recommend that you have completed an OU Science Level 1 module as S285 assumes you have an understanding of some basic scientific and mathematical concepts and study skills at least equivalent to this level. These modules include: *S111 Questions in Science* and *S112 Science: concepts and practice*. As an alternative, you should, fairly recently, have taken and obtained good marks in modules equivalent to GCE A-level or level 3 vocational qualification standard in science, including biology and chemistry.

We recommend that you revise the essential Level 1 concepts before your study of S285 commences; and to help you do so, the S285 module team has compiled a primer containing some useful reference materials that you can access through the S285 module website.

4. General study skills

It is expected that you will already have achieved some degree of competency in the study skills listed below.

Basic study skills
You will have:

- an ability to organise your study time and pace it.
- An ability to analyse tasks and plan how to tackle them.
- A willingness learn from feedback provided.

Obtaining, evaluating and interpreting information
You will be able to:

- Read effectively to distinguish relevant from irrelevant or redundant information and analyse data from scientific text and images;
- locate and consult a range of online module materials (including video, audio and interactive activities) in order to obtain information and clarify complex ideas;
- synthesise information, including being able to identify arguments and alternative interpretations.

Writing skills
You will be able to**:**

- Present information in a range of formats, e.g.reports, short answers to questions, based on information and data abstracted from module materials and scientific texts, making references where appropriate, and ensuring that arguments, ideas and information are presented in a logical sequence.

Collaborative skills
You will be able to:

- Work as part of a team in collaborative activities.
- Share information collected from a variety of sources (online and remote experiments, research articles) via wikis or forums.

Computing skills
You should be familiar with:

- Word processing software such as Microsoft Word for completing TMAs
- Using online forums

4.1 Suggested further reading for skills

Northedge, A. et al. (1997) The Sciences Good Study Guide, Open University Press. ISBN 0 7492 3411 3. https://help.open.ac.uk/students/_data/documents/helpcentre/good-study-guide.pdf

Northedge, A. (2005) The Good Study Guide, Open University Press. ISBN: 0749259744.

Additionally a variety of support relating to general skills is available within the '[Study Skills]' section of StudentHome.

5. Key concepts for S285

The section sumarizes some of the key concepts with which you should be familiar before you begin your study of S285. S285 is a multidisciplinary module and you will be required to complete activites underpinned by both biological *and* chemical concepts. Emboldened terms are key words that should help you in your search for relevant background information on a particular topic.

5.1 Chemical concepts

An understanding of chemical concepts underpins many of the processes discussed in S285.

5.1.1 Elements, atoms, molecules and compounds

An **element** is a substance which cannot be broken down into simpler components by a chemical reaction. Each element is composed of a single type of **atom**. For example, the element hydrogen consists of hydrogen atoms. Every atom has a nucleus at its centre which consists of protons and neutrons. The nucleus is surrounded by particles known as electrons. Protons are positively charged, neutrons have no charge and electrons are negatively charged. Protons and neutrons each have approximately the same mass, whereas the mass of an electron is much smaller, and in fact negligible, for practical purposes. An atom has no overall electrical charge because the number of protons in an atom equals the number of electrons and so the positive charge of the nucleus is exactly balanced by the surrounding electrons, each of which carries a negative charge equal and opposite to the charge of a proton. Some common elements exist as diatomic **molecules**, e.g. the gases oxygen (O_2), hydrogen (H_2), nitrogen (N_2) and chlorine (Cl_2), which each contain two identical atoms bonded together by covalent interactions (see next section). Atoms of different elements may combine to form a more complex structure called a **compound**, e.g. sodium chloride (NaCl). In each case, the chemical formula of the compound indicates the relative numbers of the different atoms that combine together in its formation.

SAQ 1
(a) How many atoms of nitrogen are there in a molecule of nitrogen gas?
(b) What are the relative numbers of the three different atoms, hydrogen (H), phosphorous (P) and oxygen (O), in the compound phosphoric acid (H_3PO_4)?

5.1.2 Chemical reactions

In a chemical reaction **reactants** are converted into different substances called **products**. In order for a chemical reaction to occur, the reactant molecules must collide with sufficient kinetic energy. Most chemicals reactions do not therefore occur spontaneously at any measurable rate because they cannot overcome this energy barrier. A reaction with a large energy barrier can be made possible by introducing a **catalyst**, a substance that increases the rate of a reaction, but is not itself used up during the reaction.

SAQ 2 Identify two factors that can increase the rate of collision of reactant molecules and thus speed up a chemical reaction.

5.1.3 The mole

The **mole** is used to quantify the number of atoms or formula units involved in a reaction or contained in a volume of gas or solution. The relative atomic mass in grams of every element contains exactly the same number of atoms. Consequently, the mole is defined as the amount of substance containing the same number of particles as there are atoms in exactly 12 g of ^{12}C. This number is called Avogadro's constant, and it has a value 6.022×10^{23} mol^{-1}.

The mass of a mole of a substance is obtained by adding together the relative atomic masses of all of the atoms in the formula unit, and following this by the unit of mass, g (grams).

Concentrations of solutions are commonly expressed as the number of moles of solute dissolved in 1 dm^3 of solution (mol dm^{-3}).

SAQ 3
9.8 g of sulfuric acid (H_2SO_4) is dissolved in water so that the total volume is 250 cm^3. Express the concentration of the resulting solution in mol dm^{-3} (the relative atomic masses of the elements concerned are H = 1, S = 32; O = 16).

5.1.4 Chemical equations

Chemical equations are written showing the reactants on the left-hand side and the products on the right-hand side. These are connected by an arrow indicating the direction of the reaction, as in Reaction 1. As atoms are neither created nor destroyed during chemical reactions, the number of atoms of each type present on one side of the equation must be the same as the number of each type on the other side, i.e. the equation must be **balanced**. If a chemical equation is balanced, in other words, if the numbers of each type of atom, and the overall electric charge, are exactly the same on both sides of the equation, then the arrow is replaced by an equals sign (as in Reaction 2).

$Na(s) + Cl_2(l) \rightarrow NaCl(s)$ (R1)
$2Na(s) + Cl_2(l) = 2NaCl(s)$ (R2)

On each side of the balanced Equation 2, there are two sodium atoms and two chlorine atoms, and an overall electric charge of zero. The physical **states** of reactants and products are denoted by suffixes: (s) for solid, (l) for liquid, (g) for gas and (aq) for aqueous solution.

SAQ 4
(a) Balance the following equation for the combustion of heptane, C_7H_{16}.

$C_7H_{16}(l) + O_2(g) \rightarrow CO_2(g) + H_2O(g)$ (R3)

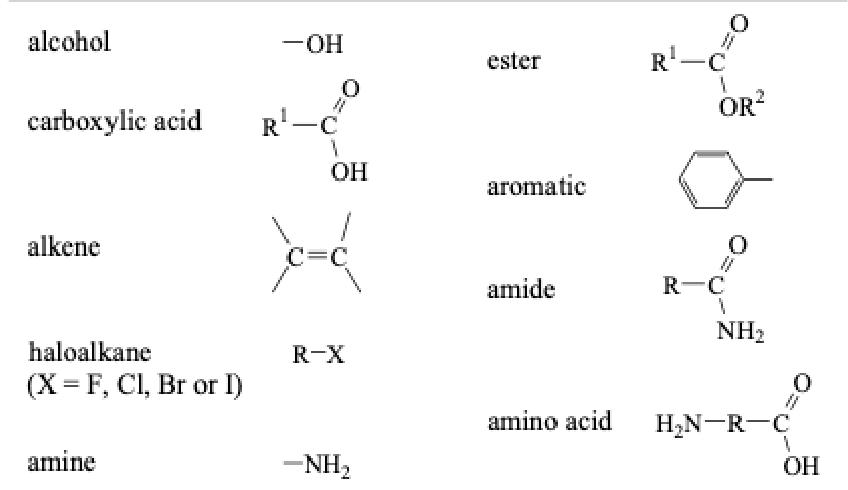
(b) During the process of photosynthesis, green plants use atmospheric carbon dioxide (CO_2) and water (H_2O) to produce glucose ($C_6H_{12}O_6$). Balance the left-hand side of the following overall chemical equation for this reaction, so that you have the correct numbers of molecules of the reactants.

$?CO_2 + ?H_2O = C_6H_{12}O_6 + 6O_2$ (R4)

5.1.5 Organic compounds, functional groups and biological macromolecules

Organic compounds contain carbon. Living cells synthesise large organic **macromolecules**, which typically consist of long chains or rings of carbon with other atoms (usually hydrogen, oxygen and nitrogen) attached. The most common organic macromolecules in living organisms are carbohydrates (sugars), proteins, lipids (fats) and nucleic acids, which cells synthesise by linking together simple monomers in a series of reactions, in which two organic molecules are covalently joined together to make a larger, more complex molecule.
In many reactions of organic compounds, only certain groups of atoms are directly involved. It is the nature of these groups of atoms that primarily determines the type of reaction that takes place, and the particular chemical properties of an organic molecule. Such groups of atoms are called **functional groups**. Some functional groups that you should be familiar with are shown in Table 1.

Table 1 Some functional groups that you should be familiar with



In Table 1, the symbols R, R^1 and R^2 are used to represent different hydrocarbon groups, or the rest of the molecule.

In protein synthesis, the monomers to be joined are amino acids which each have two functional groups: an amino group ($-NH_2$) at one end and a carboxylic acid group (-COOH) at the other. The amino group of one amino acid reacts with the carboxylic acid of another amino acid, with the loss of a water molecule, to form a covalent bond called a peptide bond. The joining of two amino acids forms a dipeptide, and sequential addition of many amino acids by condensation forms a long chain called a polypeptide. Proteins may be formed from one or more polypeptide chains.

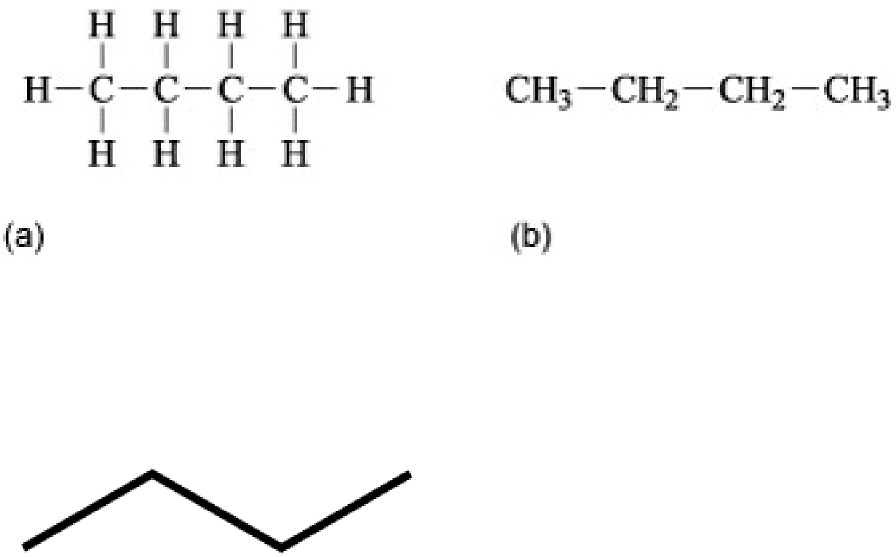
The long carbon chains of proteins and nucleic acids spontaneously fold into complex three-dimensional shapes, which are critical for their biological activities. This higher order structure is held together by many weak **non-covalent interactions** between different parts of the molecule. The four main types of non-covalent interaction involved are hydrogen bonds, ionic interactions, van der Waals forces, and hydrophobic interactions. These types of weak interaction are also involved in the many biological processes in which macromolecules bind specifically but transiently to one another.

SAQ 5
(a) What are the monomer building blocks of the following examples of macromolecules:
(i) enzymes;
(ii) RNA;

(iii) cellulose.
(b) What type of bond exists between the two separate DNA strands in the characteristic DNA double helix?

5.1.6 Drawing organic molecules

Figure 1 shows the structure of butane drawn in three different ways. Figure 1a shows the **structural formula** where all the bonds are represented. Figure 1b shows the **abbreviated structural formula** for butane. Here, only the bonds between the carbon atoms are drawn and not the bonds to the hydrogen atoms. This convention is used because structural formulae become very cumbersome when the carbon chain becomes long. With larger molecules even this abbreviated structural formula becomes cluttered. Figure 1c shows the **skeletal formula** for butane in which the C, H and C-H bonds are dispensed with so the molecule looks like a series of lines that represent the bonds holding the carbon atoms together.



(c)

Figure 1 (a) The structural formula of butane; (b) the abbreviated structural formula of butane; (c) the skeletal formula for butane.

SAQ 6

Figure 2 shows the skeletal formula of glucose. Draw the structural formula

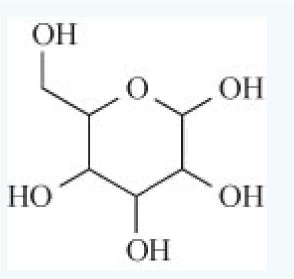


Figure 2 The skeletal formula of glucose

5.1.7 Suggested further reading for Chemical concepts

S111 *Questions in Science*: Topic 1, Topic 5 and Topic 9
S112 *Science: concepts and practice*: 'Material Worlds', 'Why Chemical reactions happen' and 'Make me a molecule'

5.2 Biological Concepts

This Section outlines the key concepts in Biology that you will need to understand before embarking on S285.

5.2.1 Cell structure

At the broadest level, organisms can be divided into two groups on the basis of their cell type: organisms with **prokaryotic** cells include the mainly single-celled Bacteria and Archaea, while those with **eukaryotic** cells include protists, plants, animals and fungi, and are mostly multicellular. While all cells share certain properties, for example they are all bounded by a membrane, there are fundamental structural differences between prokaryotic and eukaryotic cells, and between the features of plant, fungal and animal cells.

SAQ 7
(a) The items in Table 2 describe features of cells. Using ticks and crosses, complete the table for a prokaryotic cell, a eukaryotic animal cell and a eukaryotic plant cell.

Table 2 Comparing prokaryotic cells, eukaryotic animal cells and eukaryotic plant cells

Feature	Prokaryotic cell	Eukaryotic animal cell	Eukaryotic plant cell
Contains a nucleus			
Possesses a cell wall			
Contains organelles			
DNA is contained within the nucleus			
Contains chloroplasts			
DNA is free within the cytoplasm			

(b) Briefly describe one function that is associated with the following structures in eukaryotic cells:
(i) cell membrane
(ii) nucleus
(iii) ribosomes

(c) Which type(s) of biological macromolecule performs each of the following functions in cells?
(i) catalytic activity
(ii) carry genetic information

5.2.2 DNA

DNA is a macromolecule consisting of two strands that coil around an axis and form a spiral, called a double helix. Each strand is composed of **nucleotides**, the building blocks of DNA. Nucleotides are units consisting of a phosphate group attached to a sugar and a nitrogen-containing base.

The heritable characteristics of an organism are determined by the structure of their **genes**, sections of the DNA genome that encode proteins, that form the cell structure and carry out cellular processes. In other words, genes determine the characteristics of the organism. The sequence of the four nucleotide bases (commonly referred to as A, G, C and T) in DNA provides the genetic code, which specifies the sequence of the amino acids within the encoded proteins. The rules of **base pairing** are the following, adenine (A) pairs with thymine (T) and cytosine (C) with quinine (G). A and G are purines, whereas T and C are pyrimidines.

SAQ 8
(a) What is meant by the term complementary base paring in DNA and why is this important?
(b) Write the complementary sequence of the following DNA template:
CGTGGATCTGG

5.2.3 DNA replication

In order to multiply, cells must grow and make a copy of their genome in a process known as **DNA replication**. They then undergo cell division to produce two daughter cells each containing one copy of the genome. Prokaryotes divide by the process of binary fission after replicating their DNA. The process in eukaryotes is more complex because the DNA is packaged into a number of individual chromosomes which must be replicated and divided equally between the daughter cells in the process of mitosis (or meiosis in germline cells).

During DNA replication a human cell has to replicate around 6 billion base pairs of DNA. That's over 200 000 base pairs per second. And it must do so making as few errors as possible.

DNA replication is performed by a number of proteins called enzymes. An **enzyme** is a biological catalyst; that is, a molecule that increases the rate of a chemical reaction. In this case, enzymes increase the rates of reaction to make them very, very fast indeed!

SAQ 9
Name the enzymes involved in DNA replication and state their roles.

5.2.4 Proteins

Proteins play a variety of roles in our bodies; some proteins are present in muscles, tendons and hair whereas others play important roles as enzymes in cells that carry out and control many bodily functions.

Proteins are examples of biological macromolecules. The monomers used to make proteins are amino acids. The sequence of amino acids in a polypeptide chain is known as its primary structure. This primary structure folds up to form the mature protein. In addition to the primary structure three more levels of protein structure can be described: secondary, tertiary and quaternary. Secondary structure depends on hydrogen bonding and involves α-helices and a ß-sheets. Tertiary structure is the overall three-dimensional shape. Quaternary involves the arrangement of polypeptide chains or subunits.

5.2.5 Protein synthesis

Protein synthesis is a biological process, in which cells make proteins. This happens in two stages: **transcription** and **translation**. During transcription a DNA segment is copied into messenger RNA (mRNA) that serves as a template for translation. Subsequently, the mRNA sequence is translated into a polypeptide. The sequence of nucleotides along the mRNA determines the amino acid sequence. Amino acids are coded for by three letter nucleotide sequences known as **codons**. Most amino acids are coded for by more than one codon (Figure 3).

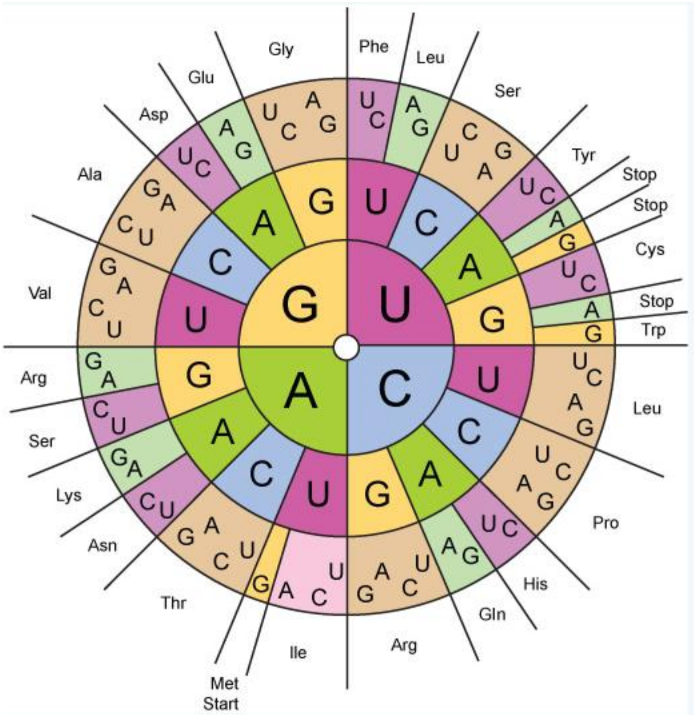


Figure 3 An RNA codon chart

SAQ 10
(a) Which of these amino acids is encoded by CCA?
Thr
His
Pro
Leu

5.2.6 Suggested further reading for Biological concepts

S111 *Questions in Science*: Topic 2 and Topic 6
S112 *Science: concepts and practice*: ‘DNA’, ‘Proteins’ and ‘The Multicellular organism’

6. Mathematical skills

You should be able to perform simple calculations. The following basic mathematical skills are also relevant to S285.

6.1 Mean, median and mode

In everyday terms, you will be familiar with the meaning of the word ‘average’, but in science and statistics there are actually several different kinds of average used for different purposes.
The **mean** is the most common measure of average. All data points are added and then divided by the total number of the data points. In biology and chemistry, mean calculations are very important for drawing conclusions and validating methods. Thus, are frequently used in many experimental investigations.

The **median** is the middle value in a series when the values are arranged in order of size. If there are two middle numbers the median is the mean of those two numbers.

The **mode** is the most frequently occurring value in a set of data.

SAQ 11
What are the mean, median and mode of the following numbers?
1.5, 2, 5, 7, 10, 22.3, 27.8, 30, 33, 33, 46.7, 55.1, 68,9

6.2 Scientific (powers of ten) notation

There is a very wide range of magnitudes of numbers involved in scientific data. For instance, the distance to the nearest star is 40 000 000 000 000 000 metres, whereas the time taken by light to travel 100 metres is 0.000 000 33 seconds. It is clearly not convenient to express very large or very small numbers like these in this conventional way.
A much more manageable form, known as **scientific notation**, uses the fact that large numbers are generated by multiplying several tens together, the number of tens being indicated by a superscript called 'the **power**'. Thus:

$10 = 10^1$ (read as 'ten to the power one')
$100 = 10 \times 10 = 10^2$ ('ten to the power two')
$1\,000\,000 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 10^6$ ('ten to the power six').

The distance to the nearest star can therefore be expressed as: 4×10^{16} m (where 16 is the number of zeros involved). Similarly, the speed of light in a vacuum is approximately 300 000 000 m s^{-1}; in other words:

$3 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10$ m s–1 $= 3 \times 10^8$ m s^{-1}

Numbers less than 1 can be expressed in a similar way; for example,

$0.1 = 1/10 = 1/10^1$, which is written as 10^{-1}
and
$0.0001 = 1/10\,000 = 1/(10 \times 10 \times 10 \times 10) = 1/10^4$, which is written as 10^{-4}.

Thus, the time for light to travel 100 m can be written as 3.3×10^{-7} s.

Note that when *multiplying* values expressed using powers of 10, the powers must be *added*. For example,

$1\,000 \times 100$ becomes $10^3 \times 10^2 = 10^{(3+2)} = 10^5 = 100\,000$
In order to raise a power by a further power, the powers must be *multiplied*. For example, $(10^3)^4 = 10^{(3 \times 4)} = 10^{12}$

SAQ 12
(a) Express the following numbers using scientific (powers of 10) notation:
(i) 8 970
(ii) 1 460 000
(iii) 0.0046

(b) Express the following as integers or in decimal notation:
(i) 5.89×10^3
(ii) 3.9×10^{-3}
(iii) 4.76×10^6

6.3 Units

All measured quantities must have units associated with them. The units used in science are known as **SI units**. SI is an abbreviation of 'Système International d'Unités' (international system of units). The advantage of having a standard set of units is that everyone uses the same system, and there is therefore no need to convert laboriously from one system to another in order to compare results from different countries. In the SI system, all units are related to seven base units (Table 3).

Table 3 The seven SI base units

Physical quantity	**Name of unit**	**Symbol for unit**
Length	metre	m
Time	second	s
Mass	kilogram	kg
Temperature	kelvin	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

SI units are often used with prefixes which are based on multiples of 1000. The most commonly used prefixes are listed in Table 4.

Table 4 Prefixes used with SI units.

Prefix	**Symbol**	**Multiplying factor**
Giga	G	10^9
Mega	M	10^6
Kilo	k	10^3
-	-	10^0
Milli	m	10^{-3}
micro	μ	10^{-6}
Nano	n	10^{-9}
Pico	p	10^{-12}
femto	f	10^{-15}

6.4 Rearranging equations

The following equation:

$PV = nRT$ (Eqn 1)

is the ideal gas law, relating four gas variables and one constant. The variables are pressure (P), volume (V), number of gas (n) and temperature (T). The constant R is the ideal gas law constant. Suppose that want to find *n* and you know *P* and *V* and *T*. The best way to proceed is to rearrange the equation to make *n* the **subject** of the equation, where the word 'subject' is used to mean the term written by itself, usually to the left of the equals sign. That is an equation that starts:

$n =$

There are many different methods taught for rearranging equations, and if you are happy with a method you have learnt previously it is probably best to stick with this method.
Returning to equation , to arrange the equation so that *n* is the subject, you could proceed as follows

$nRT = PV$ (Eqn 2)

dividing both sides by RT to give

$n = \frac{PV}{RT}$ (Eqn 3)

SAQ 13
The equation for a straight line on a graph is given as:

$y = mx + c$ (Eqn 4)

Where *x* and *y* are values on the x and y axes, *m* is the slope of the line and *c* is the intercept of the line of the y axis.
Rearrange the equation to make *x* the subject.

6.5 Graphical applications

The significance of trends in data is often seen more clearly when those data are presented in the form of a **graph**. For example, a plot of distance travelled against time (as in Figure 4) allows us to calculate **velocity**. The independent variable is always on the x axis (horizontal line) and the dependent variable on the y axis (vertical line).

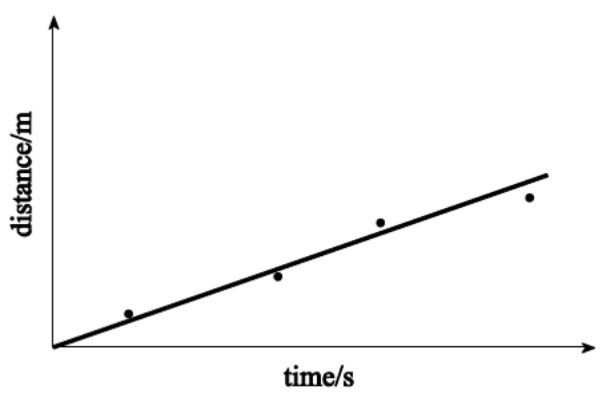


Figure 4 Distance (on the vertical, *y*, axis) plotted against time (on the horizontal, *x*, axis).

A linear plot (with *y* plotted against *x*) is represented by the equation:

$y = mx + c$ (Eqn 4 repeated)

where *m*, the **proportionality constant**, corresponds to the slope (**gradient**) of the straight line, and *c* corresponds to the value of the intercept of the line with the y axis; in this example $c = 0$, because the line cuts the vertical axis (and the horizontal axis in this particular case) at the value $y = 0$. The slope (gradient), *m* is given by:

$m = (y1 - y2)/(x1 - x2)$ (Eqn 5)

where (*x*1, *y*1) and (*x*2, *y*2) are the coordinates of any two points on the line.

Not all graphs are straight lines, as Figure 5 shows. The plots in Figure 5 illustrate the progress of the reaction (Reaction 5):

$S_2O_8^{2-}(aq) + 2I^-(aq) = 2SO_4^{2-}(aq) + I_2(aq)$ (R5)

for a *fixed* initial concentration of iodide ions and various initial concentrations of peroxodisulfate ions ($S_2O_8^{2-}$). The initial concentration of $S_2O_8^{2-}$ increases as you go from curve (a) to curve (d).

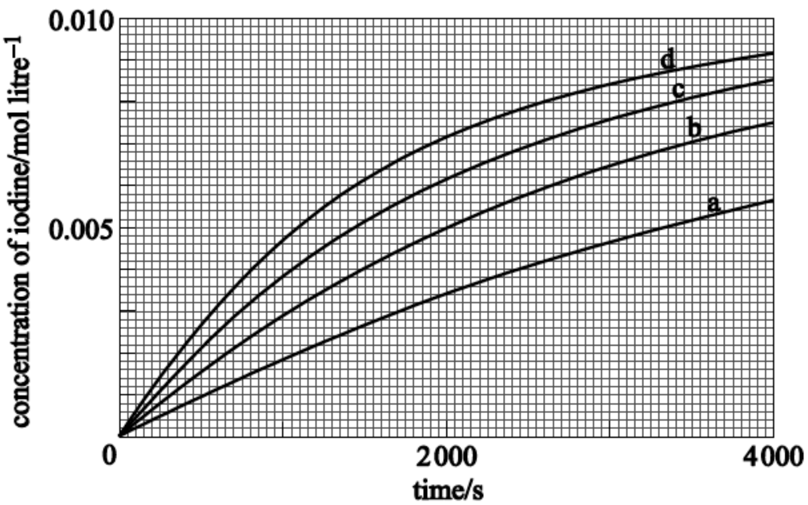


Figure 5 The progress of Reaction 5 (R5) as measured by the increase in the concentration of iodine at 25 °C for four different initial concentrations of peroxodisulfate ($S_2O_8^{2-}$) ions, a, b, c and d.

In Figure 5, the early part of each reaction-progress curve approximates to a straight line. For example, curve (a) from 0 to 1 500 s, and curve (d) from 0 to 400 s. For all four lines the value of *c* is 0 because they all cut the *y* axis (showing the concentration of iodine) at the point where the value of *y* is zero.
Experimental data will not normally lie exactly in a straight line, and a ‘best fit’ line should be drawn. The gradient of such a line can be calculated by selecting two points on the line

and dividing the difference in their corresponding values of *y* by the difference in their values of *x*.

SAQ 14
Give the definition of best fit line.

6.6 Suggested further reading for Mathematical skills

Maths Skills Ebook
Succeed with maths – Part 1 and Part 2
Maths resources are also available in the 'Study skills' section of StudentHome.

7. Practical skills

The ability to ask well designed scientific questions and address them in a safe, ethical manner is a key skill for science-related subjects like chemistry and biology that will form a large part of your studies on S285.

7.1 Variables

To understand a complex experiment it is essential to appreciate the variables that contribute to the result. There are several different types of variable, the three most relevant for us are dependent, independent and controlled.
SAQ 15
Give definitions for dependent, independent and controlled variables.

7.2 Scientific methods – hypotheses and null hypotheses

Before beginning an investigation a hypothesis is needed. Hypotheses are predictions that can be tested by experiment or observations. Statistical hypothesis testing can be applied to data to determine whether or not a difference exists. Scientists are required by this procedure to put forward a so-called **null hypothesis** in the first instance. This is a hypothesis of *no difference*.

SAQ 16
The hypothesis for an investigation into the effect of aspirin on blood glucose levels is that taking aspirin will decrease blood glucose levels. What would be the null hypothesis for this investigation?

7. 3 Lab safety and risk assessment

New experiments require a detail risk assessment, in which potential hazards are identified and actions or controls are determined to reduce the associate risks. Fail to comply with risk assessment may result to negative consequences affecting the safety of scientists conducting the experiments, other laboratory users and the surrounding environment.

SAQ 17
Identify three things that should be included in a risk assessment.

7.4 Record keeping

Laboratory record keeping is a good practise and essential part of all scientific investigations. As a scientist, you have a responsibility to clearly evidence how you achieved the results you are reporting. Comprehensive laboratory notes on methods enable you and equally importantly, others, to replicate your experiment. Memory can be very unreliable and having a written record of methods and results enables you to return to the data at a later date.

SAQ 18

List some things that should be recorded as a part of scientific investigations.

7.5 Suggested further reading for Practical skills

S112 *Science concepts and* practice: Topic 8 practical work (observational) and Topic 20 practical work (controlling variables)

Good experiment guide

8. And finally...

We hope that this diagnostic booklet has given you a good idea of what to expect in S285 and how studying this module is essential for progressing your Level 2 studies as well as helping you to develop the skills required for Level 3. We trust that you have found it interesting and we look forward to welcoming you to the module.

Answers to self-assessment questions

SAQ 1

(a) The subscript ‘2’ in N_2 indicates that there are two nitrogen atoms.

(b) The symbol for phosphorous has no subscript, so there is only one atom of phosphorous. However, the symbol for hydrogen has the subscript ‘3’, so there are three atoms of hydrogen indicated in the chemical formula. Similarly, the symbol for oxygen has the subscript ‘4’, so there are four atoms of oxygen indicated in the chemical formula. The relative number of atoms indicated by the chemical formula is therefore 3 hydrogen: 1 phosphorous: 4 oxygen.

SAQ 2

The rate of collision of molecules can be increased by increasing the concentration of the molecules, increasing the temperature which gives the molecules more kinetic energy, so they move faster and interact more often.

SAQ 3

The molar mass of H_2SO_4 corresponds to the sum of the relative atomic masses of two hydrogen atoms, one sulfur atom and four oxygen atoms; expressed in grams this is $(1 \times 2) + 32 + (16 \times 4) = 98$ g. Therefore, 9.8 g corresponds to 0.1 mol. This amount is dissolved in 250 ml, which is 250/1 000 litre = 0.25 litres of solution. Since the concentration is the amount (in moles) dissolved in 1 litre of solution, the concentration of this solution is $4 \times 0.1 = 0.4$ mil litre−1.

SAQ 4

(a) $C_7H_{16}(l) + 11O_2(g) \rightarrow 7CO_2(g) + 8H_2O(g)$

There are seven carbon atoms, sixteen hydrogen atoms and twenty-two oxygen atoms, in each site of equation.

(b) The balanced equation is:

$$6CO_2 + 6H_2O = C_6H_{12}O_6 + 6O_2$$

SAQ 5

(a)

(i) enzymes are proteins, so the monomers are amino acids;

(ii) RNA is a nucleic acid, so the monomers are nucleotides;

(iii) cellulose is complex carbohydrate; a polysaccharide, so the monomers are monosaccharide (more specifically, glucose).

(b) Non-covalent hydrogen bonds between the nucleotides of the two DNA strands help to maintain the double helical structure.

SAQ 6

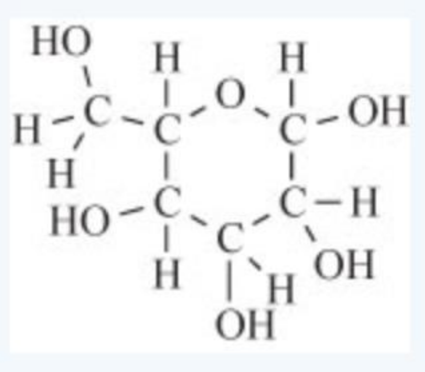


Figure 6 The structural formula of glucose

SAQ 7

Table 2 (complete) Comparing prokaryotic cells, eukaryotic animal cells and eukaryotic plant cells

(a)

Feature	**Prokaryotic cell**	**Eukaryotic animal cell**	**Eukaryotic plant cell**
Contains a nucleus	✗	✓	✓
Possesses a cell wall	✓	✗	✓
Contains organelles	✗	✓	✓
DNA is contained within the nucleus	✗	✓	✓
Contains chloroplasts	✗	✗	✓
DNA is free within the cytoplasm	✓	✗	✗

(b) These functions are:
(i) The cell membrane is a selectively permeable barrier between the interior of the cell and the outside environment; it allows the control of the passage of molecules in and out of the cell.
(ii) The nucleus contains the cell's genetic material (DNA).
(iii) Ribosomes are the site of protein synthesis in cells.

(c) These biological macromolecules are:
(i) Globular proteins called enzymes have catalytic activity.
(ii) Nucleic acids carry genetic information.

SAQ 8

(a) Complementary base pairing is the phenomenon where adenine (A), on one DNA strand always forms hydrogen bonds with thymine (T) on the opposite DNA strand and cytosine (C) on one DNA strand always forms hydrogen bonds with guanine (G) on the other strand. It is important because it is essential in forming the helical structure of DNA and it provides an

explanation for how DNA can mediate genetic inheritance through semiconservative replication.
(b) The complementary sequence of CGTGGATCTGG is GCACCTAGACC

SAQ 9
The enzymes involved in DNA replication are:
DNA helicase which catalyses the separation of double stranded DNA into individual strands.
DNA polymerase which catalyses the synthesis of a new DNA strand using the original strand as a template.
DNA ligase which catalyses the joining together (ligation) of short pieces of single stranded DNA into longer strands of DNA.

SAQ 10
By reading the codon chart you can determine the amino acid. Select the first base letter C in the centre of the wheel, then the second base letter C from the middle ring and lastly the third base letter A from the outside ring. The amino acid is proline.

SAQ 11
For the values 1.5, 2, 5, 7, 10, 22.3, 27.8, 30, 33, 33, 46.7, 55.1, 68,9

Mean = $\frac{1.5+2+5+7+10+22.3+27.8+30+33+33+46.7+55.1+68.9}{13} = 26.3$ (Eqn 6)

The median value is the middle value in the series. In this case 27.8.
The mode is the most frequently occurring value. In this case the mode is 33 which occurs twice whereas all other numbers occur once.

SAQ 12
(a)
(i) 8.97×10^3
(ii) 1.46×10^6
(iii) 4.6×10^{-3}

(b)
(i) 5890
(ii) 0.0039
(iii) 4 760 000

SAQ 13
To rearrange Equation 4 to make *x* the subject:

$y = mx + c$ (Eqn 4 repeated)

subtracting *c* from both sides of Equation 4 gives:

$y - c = mx$ (Eqn 7)

Then dividing both sides of Equation 7 by *m* gives:

$\frac{y-c}{m} = x$ (Eqn 8)

Which can also be written as:

$x = \frac{y-c}{m}$ (Eqn 9)

SAQ 14
The best fit line (trendline) refers to a straight line that passes through a scatter plot of data.

SAQ 15
Dependent variable
A measured quantity, the value of which depends on the value chosen for another quantity (the independent variable). On a graph, the dependent variable is plotted on the y axis. For example, if an investigator selected children of certain ages and measured their heights, then height would be the dependent variable.

Independent variable
A quantity, the value of which is chosen by the investigator. On a graph, the independent variable is plotted on the x axis. For example, if an investigator selected children of certain ages and measured their heights, then age would be the independent variable, and height the dependent variable

Controlled variable
Potential variables that are held constant to make the results of the experiment intelligible. Controlled variables can affect experimental outcome just as the independent variables do, so they are held constant to ensure that the effects observed are caused by the changes made to the independent variable.

SAQ 16
The null hypothesis for the investigation would be that taking aspirin has *no effect* on blood glucose levels.

SAQ 17
Things that should be in a risk assessment include:

- Identified hazards
- The risk that they pose
- Working personnel who might be affected by the risk.
- How likely the risks are (risk rating).
- Control measures to eliminate the risk
- Review date.

SAQ 18
Some things that should be recorded as part of a scientific investigation include:

- The date
- What was done and why (the research question and hypotheses)
- How it was done (the method and equipment used)
- What happened (the results of the experiment(s) including any measurements, observations and other data collected)
- Any data analysis and interpretation that was carried out
- Any unexpected occurrences, such as equipment or handling errors