1 Introduction

This self-assessment quiz aims to help you decide if you are ready to study S248 *Chemistry in life: food, water and medicines*, and to identify areas of chemistry and general scientific skills (including maths) that you need to be familiar with before committing yourself to the module. The questions are grouped along these lines, and answers are provided at the end of the item so you can check whether you’ve answered correctly. (There are also references in the answers to potentially useful parts of other OU modules that you may already have studied – more details about prior study are provided in Section 2.)

You may wish to revise or study before undertaking the *Are you ready for?* quiz, or you may try the quiz, study and then come back and try it again. You shouldn’t expect to be able to answer all the questions 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.

Before starting this quiz, you should read the description of the module. It outlines the topics, the assessment strategy and the study materials that will be provided in S248. You should also read carefully the other comments on time commitments and study skills required for S248, and be very honest with yourself when deciding if this is the right module for you.

Ultimately the choice to register for S248 is yours to make, but this quiz is designed to help inform your decision. We would encourage you to discuss your module choices with study advisers before registering.
S248 is a compulsory component of the R59 Chemistry degree. It can also be taken:

- as part of a number of other science degrees, diplomas or certificates
- in the Open Degree
- as a stand-alone module.

To complete this self-assessment you will need a (basic scientific) calculator, and a pen/pencil and paper. For reference, a Periodic Table is provided at the end of the quiz.

2 Prior study

We strongly recommend that you have completed an OU Science Level 1 module, as S248 assumes you have an understanding of some scientific and mathematical concepts, and study skills at least equivalent to this level. These modules include: S111 Questions in science; S112 Science: concepts and practice; and S104 Exploring science (now discontinued). Alternatively, 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 chemistry. Or you may be studying S248 using credit transfer, after completing a HNC or HND in Applied Sciences.

We recommend that you revise the essential Level 1 concepts before your study of S248 commences. To help you do so, the S248 module team has compiled some useful reference materials (the S248 Primer) that you can access through the S248 module website, if you decide to enrol on the module.

3 Study skills

It is expected that you will already have achieved some degree of competence of the skills listed in Table 1. However, during your participation in the module, it is hoped you will refine and develop these skills further and extend your competence.

Table 1 Examples of study skills that are relevant to S248.

<table>
<thead>
<tr>
<th>Skill type</th>
<th>Practical examples</th>
</tr>
</thead>
</table>
| General study skills | organising your study time  
| | pacing your study  
| | effective reading to identify and extract relevant information from irrelevant or redundant material from texts and other media  
| | retrieving data from scientific texts and accounts. |
| Writing skills | writing coherently  
| | structuring and presenting arguments in a logical sequence often based on a range of sources, including published papers, websites, tables and diagrams  
| | writing a scientific account with appropriate diagrams. |
| Cognitive skill | recognising trends and patterns in data  
| | using evidence to support or refute theories and arguments  
| | assessing the adequacy/limitations of explanations. |
| Problem-solving skills | solving problems using given evidence (including negative evidence), and using more than one source of information. |
Table 1 (continued) Examples of study skills that are relevant to S248.

<table>
<thead>
<tr>
<th>Skill type</th>
<th>Practical examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Computer skills</td>
<td>• word processing and spreadsheet skills</td>
</tr>
<tr>
<td></td>
<td>• familiarity with Windows operations and web browsers</td>
</tr>
<tr>
<td></td>
<td>• manipulating diagrams for inclusion in tutor-marked assignments (TMAs)</td>
</tr>
<tr>
<td></td>
<td>• familiarity with online forums</td>
</tr>
<tr>
<td></td>
<td>• searching online for data.</td>
</tr>
<tr>
<td>Collaborative skills</td>
<td>• working as part of a team in a collaborative activity involving experimental design</td>
</tr>
<tr>
<td></td>
<td>• organising and distributing tasks, and presenting findings</td>
</tr>
<tr>
<td></td>
<td>• sharing data using forum posts or wikis.</td>
</tr>
</tbody>
</table>

4 Self-assessment quiz

Section 1 Atomic structure, chemical formulae and chemical bonding

Question 1

(a) Give the name of the element, and the number of protons and electrons for Mg\(^{2+}\).
(b) Is Mg\(^{2+}\) a neutral atom, an anion or a cation?

Question 2

How many outer (or valence) electrons do each of the following atoms have?
(a) Na
(b) Cl
(c) C
(d) S

Question 3

(a) Write down the number of each type of atom in following chemical formulae:
   (i) CaCl\(_2\)
   (ii) CH\(_2\)CH\(_2\)OH
   (iii) CH\(_3\)CHBrCH(CH\(_3\))COOH
   (iv) Ca\(_3\)(PO\(_4\))\(_2\)
(b) Which of the following pairs of atoms would form covalent bonds?
   (i) Calcium and oxygen
   (ii) Carbon and fluorine
   (iii) Carbon and hydrogen
(c) Write down the formula of compounds formed between
   (i) Sodium and oxygen
   (ii) Oxygen and fluorine
Question 4

Draw a (Lewis) dot-and-cross diagram to represent the bonding in the following compounds
(a) CH₄
(b) MgCl₂

Question 5

Which of the following covalent bonds would you expect to be polar?
(a) A bond between carbon and oxygen.
(b) A bond between carbon and fluorine.
(c) A bond between carbon and hydrogen.

Question 6

(a) Draw a simple representation of a water molecule in which you indicate the polar nature of the bonds.
(b) Draw three or more water molecules to illustrate the hydrogen bonds that exist between them.

Section 2 Chemical equations and mole calculations

Question 7

Balance the following chemical equations:
(a) Na(s) + Cl₂(g) = NaCl(s)
(b) CaCO₃(s) + HCl(aq) = CaCl₂(aq) + CO₂(g) + H₂O(l)
(c) C₃H₆O(l) + O₂(g) = CO₂(g) + H₂O(l)

Question 8

Calculate the mass of Na₂CO₃ required to react with 0.30 moles of HCl, given the following balanced equation:
Na₂CO₃ + 2HCl = 2NaCl + CO₂ + H₂O
(The relative atomic masses of the elements concerned are Na = 23, C = 12; O = 16.)

Question 9

In an experiment, 9.8 g of sulfuric acid (H₂SO₄) is dissolved in water so that the total volume is 250 cm³. Express the concentration of the resulting solution in mol litre⁻¹. (The relative atomic masses of the elements concerned are H = 1, S = 32; O = 16.)
Section 3 Acids, bases, oxidation and reduction

Question 10

Are the following aqueous solutions acidic, neutral or alkaline? Give your reasons.

(a) A solution of NaOH.
(b) A solution of HCl.
(c) A solution of NaCl.

Question 11

Calculate the pH of a solution containing HCl at concentration 0.2 mol litre⁻¹.

Question 12

For each of the following reactions, state whether they represent oxidation or reduction.

(a) Fe²⁺(aq) + 2e⁻ = Fe(s)
(b) Cr₂O₄²⁻(aq) + 14H⁺(aq) + 6e⁻ = 2Cr³⁺(aq) + 7H₂O(l)
(c) Ag(s) = Ag⁺(aq) + e⁻

Section 4 Energy changes during chemical reactions

Question 13

Which of the two energy level diagrams in Figure 1 represents an exothermic reaction?

Figure 1 Two energy level diagrams.
Question 14

State two ways of increasing the rate a of chemical reaction.

Question 15

(a) Use Table 2 to calculate the overall molar enthalpy change for the reaction

\[ \text{CH}_4(g) + 2\text{Cl}_2(g) = \text{CCl}_4(g) + 2\text{H}_2(g) \]

(b) Is this reaction endothermic or exothermic? State your reasoning.

<table>
<thead>
<tr>
<th>Bond</th>
<th>Molar bond enthalpy/kJ mol(^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>C–H</td>
<td>413</td>
</tr>
<tr>
<td>Cl–Cl</td>
<td>242</td>
</tr>
<tr>
<td>C–Cl</td>
<td>346</td>
</tr>
<tr>
<td>H–H</td>
<td>436</td>
</tr>
</tbody>
</table>

Table 2 Bond enthalpies.

Section 5 Organic compounds and chemistry

Question 16

Identify the functional groups present in the amino acid serine (Figure 2)

![Figure 2](image)

Figure 2 The structural formula of serine.

Question 17

The skeletal formula for the drug mebeverine is shown in Figure 3. Write down its molecular formula.

![Figure 3](image)

Figure 3 The skeletal structure of mebeverine.
Question 18

Which of the organic molecules shown in Figure 4, each containing the alcohol (O–H) functional group, will be most soluble in water? Briefly explain your answer.

(a) \( \text{CH}_3\text{–OH} \)
(b) \( \text{CH}_3\text{–OH} \)
(c) \( \text{CH}_3\text{–OH} \)

Figure 4 The structures of three compounds, (a)–(c), containing an alcohol functional group.

Section 6 Maths skills

Question 19

What is 8% of 400?

Question 20

How many significant figures are there in each of the following measurements?

(a) 1.970
(b) 0.0012
(c) 2.88 \( \times \) 106

Question 21

Express the following numbers using scientific (powers of 10) notation:

(a) 8970
(b) 1 467 851
(c) 0.010 01
(d) 0.0046

Question 22

Express:

(a) 100 g in kg
(b) 17 \( \mu \text{m} \) in mm
Question 23

Figure 5 is a graph showing how the surface temperature at Milton Keynes varied over a 24-hour period.

(a) What were the maximum and minimum temperatures, and at what times did they occur?

(b) What was the percentage increase in temperature between 12.00 and 18.00 h? Give your answer to two significant figures.

Figure 5 Surface temperature at Milton Keynes.

5 Answers

Question 1

(a) Mg is the symbol for the element magnesium. Mg has an atomic number of 12. It therefore has 12 protons. The ion Mg$^{2+}$ also has 12 protons. It differs from Mg by having two less electrons, so Mg$^{2+}$ has 10 electrons.

(b) Mg$^{2+}$ is a cation.

For reference, this concept is discussed in:
S111 Topic 5 Part 2
S112 Topic 11 Part 3.

Question 2

(a) Na is in Group 1 of the Periodic Table, so has one outer electron.

(b) Cl is in Group 17 (or Group 7 on some periodic tables), so has seven outer electrons.
(c) C is in Group 14 (or Group 4), so has four outer electrons.
(d) S is in Group 16 (or Group 6), so has six outer electrons.

For reference, this concept is discussed in:
- S111 Topic 5 Part 2
- S111 Topic 9 Part 1

**Question 3**

(a) (i) CaCl₂ contains one calcium and two chlorine atoms.
(ii) CH₃CH₂OH contains two carbon atoms, six hydrogen atoms and one oxygen atom.
(iii) CH₃CHBrCH(CH₃)COOH contains five carbon atoms, nine hydrogen atoms, two oxygen atoms and one bromine atom.
(iv) Ca₃(PO₄)₂ contains three calcium atoms, two phosphorus atoms and eight oxygen atoms.

For reference, this concept is discussed in:
- S111 Topic 9 Part 1

(b) Carbon and fluorine, and carbon and hydrogen bond via covalent bonding. Predominantly, covalent bonding occurs between non-metal atoms.

For reference, this concept is discussed in:

(c) (i) Sodium forms Na⁺ ions, as sodium atoms have one outer electron that is lost during ion formation. Oxygen forms O²⁻ ions, as oxygen atoms have six outer electrons and gain two electrons during ion formation. Therefore, the compound involves two Na⁺ ions and one O²⁻ ions, i.e. Na₂O.
(ii) Oxygen has two unpaired electrons it can use for covalent bonding, whereas fluorine has one. Therefore, two fluorine atoms are required to covalently bond with one oxygen atom, i.e. OF₂.

For reference, this concept is discussed in:
- S111 Topic 1 Part 1
- S111 Topic 5 Part 2
- S112 Topic 11 Part 3
Question 4

(a) CH₄ is a covalent molecule (as both carbon and hydrogen are non-metals), so the bonding involves sharing of electrons, as shown in Figure 6.

```
H
H x C x H
x
H
```

Figure 6 Lewis dot and cross diagram for CH₄.

(b) MgCl₂ is an ionic compound (Mg is a metal, whereas chlorine is a non-metal). In ionic compounds electrons are transferred rather than shared. The bonding is shown in Figure 7. Here the Mg has transferred two electrons (shown by dots) to chlorine. Note, square brackets are sometime placed around ions, as has been shown with the Cl⁻ ions in Figure 7.

```
Mg²⁺ [ ]⁻
[ ]⁻
```

Figure 7 Lewis dot and cross diagram for MgCl₂.

For reference, this concept is discussed in:
S111 Topic 1 Part 1
S111 Topic 9 Part 1

Question 5

(a) A covalent bond between carbon and oxygen would be polar as oxygen is significantly more electronegative than carbon.

(b) A covalent bond between carbon and fluorine would be polar as fluorine is significantly more electronegative than carbon.

(c) A covalent bond between carbon and hydrogen would be non-polar as both atoms have similar electronegativities.

For reference, this concept is discussed in:
S111 Topic 1 Part 1
S112 Topic 13 Part 3
S112 Topic 14 Part 3.
Question 6

(a) The polar nature of a covalent bond is conveyed by using δ+ (delta with a plus sign) to indicate the atom carrying the partial positive charge, and δ− (delta with a minus sign) to indicate the atom carrying the partial negative charge. In water, the O atom is more electronegative than the H atoms, hence the polarity of the covalent bonds, as represented in Figure 8.

![Figure 8](image1)

**Figure 8** Representation of the chemical structure of a water molecule showing the polar nature of the covalent bonds.

(b) Your hand-drawn figure should look similar to Figure 9. Hydrogen bonds are usually represented by dashed lines between the participating electronegative atom in one molecule or group and the participating H atom (with its partial positive charge) in the other molecule or group. Note that the direction of the hydrogen bond is the same as that of the covalent bond between the participating H atom and the O atom to which it is covalently attached.

![Figure 9](image2)

**Figure 9** Hydrogen bonding between three water molecules.

For reference, this concept is discussed in:
- S111 Topic 1 Part 1
- S112 Topic 14 Part 3.
**Question 7**

(a) \(2Na(s) + Cl_2(g) = 2NaCl(s)\)
(b) \(CaCO_3(s) + 2HCl(aq) = CaCl_2(aq) + CO_2(g) + H_2O(l)\)
(c) \(C_3H_6O(l) + 4O_2(g) = 3CO_2(g) + 3H_2O(l)\)

For reference, this concept is discussed in:
- S111 Topic 1 Part 1
- S111 Topic 5 Part 2

**Question 8**

The balanced equation you have been given is:

\[Na_2CO_3 + 2HCl = 2NaCl + CO_2 + H_2O\]

The ratio between Na\(_2\)CO\(_3\) and HCl is 1 : 2, so 0.30 moles of HCl reacts with 0.15 moles of Na\(_2\)CO\(_3\).

The molar mass of Na\(_2\)CO\(_3\) is

\[(2 \times 23) \text{ g mol}^{-1} + 12 \text{ g mol}^{-1} + (3 \times 16) \text{ g mol}^{-1} = 106 \text{ g mol}^{-1}\]

Therefore, the mass of Na\(_2\)CO\(_3\) required for the reaction is

\[
\text{Mass of Na}_2\text{CO}_3 = \text{moles Na}_2\text{CO}_3 \times \text{molar mass Na}_2\text{CO}_3
\]

\[= 0.15 \text{ mol} \times 106 \text{ g mol}^{-1}
\]

\[= 15.9 \text{ g}\]

For reference, this concept is discussed in:
- S111 Topic 4 Part 3

**Question 9**

The mass of 1 mole of H\(_2\)SO\(_4\) 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 \((1 \times 2) + 32 + (16 \times 4) = 98 \text{ g}\), so the molar mass is 98 g mol\(^{-1}\).

Therefore, 9.8 g corresponds to 0.1 mol. This amount is dissolved in 250 ml, which is 250/1000 litre = 0.25 litres of solution. Since the concentration is the amount (in moles) dissolved per litre, the concentration of this solution is (0.1 mol/0.25 litres) = 0.4 mol litre\(^{-1}\).

For reference, this concept is discussed in:
- S111 Topic 4 Part 3
- S112 Topic 20 ‘Chemistry of Cool’ practical.
Question 10

(a) When NaOH dissolves in water, OH\(^{-}\) ions are liberated, making the solution alkaline.

(b) When HCl dissolves in water H\(^{+}\) ions are liberated, making the solution acidic.

(c) Neither H\(^{+}\) or OH\(^{-}\) ions are liberated when NaCl dissolves in water, making the solution neutral.

For reference, this concept is discussed in:
S111 Topic 5 Part 3
S112 Topic 13 Part 3.

Question 11

As HCl is a strong acid it dissociates completely in water, therefore the concentration of H\(^{+}\) ions is 0.2 mol dm\(^{-3}\). Adding this value to the equation for determining pH:

\[
\text{pH} = -\log_{10}\left( \frac{\text{hydrogen ion concentration in mol dm}^{-3}}{\text{mol dm}^{-3}} \right)
\]

\[
= -\log_{10}\left( \frac{0.2 \text{ mol dm}^{-3}}{\text{mol dm}^{-3}} \right)
\]

\[
= 0.7
\]

For reference, this concept is discussed in:
S111 Topic 5 Part 3.

Question 12

(a) Fe\(^{2+}\) is gaining two electrons, hence this reaction represents reduction.

(b) The species on the reactant side of the reaction are gaining electrons (in fact it is the Cr atoms which are gaining these electrons), hence this reaction represents reduction.

(c) Ag is losing electrons (to form the cation Ag\(^{+}\)), hence Ag is oxidised.

For reference, this concept is discussed in:
S111 Topic 5 Part 2.
Question 13

The graph on the left of Figure 1 represents an exothermic reaction. This is because the products have a lower energy than the reactants, giving $\Delta H$ a negative sign (energy is lost to the environment).

For reference, this concept is discussed in:
S111 Topic 5 Part 2
S112 Topic 13 Part 2.

Question 14

Methods of increasing the rate of a chemical reaction include:
- raising the temperature, which increases the average energy of the collisions
- adding a catalyst, which lowers the activation energy for the reaction
- increasing the concentration of the reactants or increasing the pressure of the system (if the reaction occurs in the gas phase)
- increasing the surface area of any solids involved in a reaction.

For reference, this concept is discussed in:
S112 Topic 13 Part 2.

Question 15

(a) First you need to consider the energy required to break the bonds in $\text{CH}_4$ and $2\text{Cl}_2$. This is $4 \times \text{C–H bond energy}$ and $2 \times \text{Cl–Cl bond energy}$. From Table 2 this is:

$$(4 \times 413) + (2 \times 242) = 2136 \text{ kJ mol}^{-1}$$

Now you need to consider the energy released when $\text{CCl}_4$ and $2\text{H}_2$ are formed. Since energy is released this is negative and given by $-(4 \times \text{C–Cl bond energy})$ and $-(2 \times \text{H–H bond energy})$.

From the table this is

$$-(4 \times 346) + (-2 \times 436) = -2256 \text{ kJ mol}^{-1}$$

The enthalpy for the reaction is given by the sum of these two terms:

$$(2136 + (-2256)) = -120 \text{ kJ mol}^{-1}$$

(b) The enthalpy for the reaction is negative and so the reaction is exothermic.

For reference, this concept is discussed in:
**Question 16**

Serine contains the amine, carboxylic acid and alcohol functional groups, as shown in Figure 10.

![Functional groups of serine](image)

**Figure 10** The functional groups of serine.

For reference, this concept is discussed in:
- S111 Topic 9 Part 2
- S112 Topic 13 Part 3.

**Question 17**

To answer deduce the molecular formula from the skeletal formula, it is useful to write out the full structural formula. The full structural formula of mebeverine is shown in Figure 11.

![Full structural formula of mebeverine](image)

**Figure 11** The full structural formula of mebeverine.

Based on this structure, the molecule contains 25 carbon atoms, 35 hydrogen atoms, 1 nitrogen atom and 5 oxygen atoms. Therefore, the molecular formula is $\text{C}_{25}\text{H}_{35}\text{NOS}$.

For reference, this concept is discussed in:
- S111 Topic 9 Part 1.
Question 18

CH\textsubscript{3}OH (shown in Figure 12), will be the most soluble in water. CH\textsubscript{3}OH has the shortest hydrocarbon chain. Non-polar hydrocarbon chains do not mix well with water, as mixing them breaks the hydrogen bonds between water molecules. Therefore, the longer the hydrocarbon chain, the less soluble the alcohol.

\[
\text{CH}_3\text{—OH}
\]

**Figure 12** The structure of CH\textsubscript{3}OH.

For reference, this concept is discussed in:
S112 Topic 14 Part 3.

Question 19

\[
\frac{8}{100} \times 400 = 8 \times 4 \\
= 32
\]

For reference, this concept is discussed in:
Maths for Science Chapter 1
S111 Maths Skills.

Question 20

(a) Four significant figures (including the final zero).
(b) Two significant figures (not including the leading zeros).
(c) Three significant figures.

For reference, this concept is discussed in:
Maths for Science Chapter 2.

Question 21

(a) 8.97 \times 10^3
(b) 1.467 851 \times 10^6
(c) 1.001 \times 10^{-2}
(d) 4.6 \times 10^{-3}

For reference, this concept is discussed in:
Maths for Science Chapter 2
S111 Maths Skills
Question 22

(a) \( 1000 \text{ g} = 1 \text{ kg} \)

So, \( 1 \text{ g} = 10^{-3} \text{ kg} \)

\[ 100 \text{ g} = 100 \times 10^{-3} \text{ kg} = 0.1 \text{ kg} \]

(b) \( 1000 \mu\text{m} = 1 \text{ mm} \)

So, \( 1 \mu\text{m} = 10^{-3} \text{ mm} \)

\[ 17 \mu\text{m} = 17 \times 10^{-3} \text{ mm} = 1.7 \times 10^{-2} \text{ mm} \]

For reference, this concept is discussed in:
Maths for science Chapter 4.

Question 23

(a) The maximum temperature (25.2 °C) was measured at 18.00 (6.00 p.m.) and the minimum temperature (15.0 °C) was measured at 03.00 (3.00 a.m.).

(b) The increase in the temperature between 12.00 and 18.00 hours was 6 °C (25.2 °C − 19.2 °C). The percentage increase in temperature was therefore:

\[ \left( \frac{6}{19.2} \right) \times 100\% = 31.25\% \]

Or 31% to two significant figures.

For reference, this concept is discussed in:
Maths for science Chapter 7.
Figure 13 The Periodic Table