Year 12

Student Pack

Subject: Chemistry

Section	Contents
1	- Online resources
2	- Revision tasks
3	- Additional work and learning resources

Online Science resources

- Kerboodle – www.kerboodle.com Online access to textbooks and other resources
- Seneca – www.senecalearning.com Revision activities
- Memrise – www.memrise.com Keyword revision
- OCR – www.ocr.org.uk Exam board specific resources
- Revision science – www.revisionscience.com Online revision resources

Please use the resources above, your notes and your textbooks to work through the following exam style questions.

These are based on topics previously covered in Year 12.

Mark schemes will be emailed to you to allow you to self-assess your work.

2 Atoms, ions, and compounds
Exam-style questions

1 This question is about atomic structure.

a Complete Table 1.

Table 1 *Charges and masses of some subatomic particles, relative to the proton*

	Proton	Neutron
Relative mass		
Relative charge		

(*2 marks*)

b An atom of element X contains four times as many protons as are found in an atom of ^{12}C. An atom of element X contains 29 neutrons.

i State the number of protons found in one atom of ^{12}C.

.....

..... (*1 mark*)

ii Deduce the symbol, including mass number and atomic number, for this atom of element X.

.....

.....

..... (*2 marks*)

c The particles in each pair below differ only in the number of protons **or** neutrons **or** electrons. State what the difference is within each pair:

i ^{1}H and ^{2}H

.....

.....

..... (*2 marks*)

ii $^{31}P^{3-}$ and $^{32}S^{2-}$

.....

.....

..... (*2 marks*)

2 Sir Humphry Davy was the first to isolate potassium and magnesium in the early 1800s.

a Potassium only has two stable isotopes. These are K-39 and K-41.

i Explain, in terms of subatomic particles, the meaning of the term *isotopes*.

.....

.....

..... (*2 marks*)

ii The two isotopes of potassium have the same chemical properties. Explain why.

.....

..... (*1 mark*)

iii Use information from the Periodic Table to deduce which isotope of potassium is more abundant. Explain how you reached your answer.

.....

..... (*1 mark*)

b The Chelyabinsk meteorite hit Russia in February 2013. Meteorites often contain magnesium. The magnesium in a meteorite was analysed and was found to consist of three isotopes. Information about these isotopes is given in Table 2.

Table 2 *Relative isotopic mass and abundance of magnesium isotopes in a meteorite*

Isotope	Relative isotopic mass	Abundance (%)
Magnesium-24	24.00	74.65
Magnesium-25	25.00	10.00
Magnesium-26	26.00	15.35

i Calculate the relative atomic mass of this sample of magnesium. Give your answer to **two** decimal places.

Relative atomic mass = ... (*2 marks*)

ii Suggest a reason why the relative atomic mass of magnesium stated in the Periodic Table differs from your value calculated in part **i**.

.....

.....

(*1 mark*)

3 A mass spectrometer measures the relative abundance of ions with different *m*/*z* values.

a Explain the meaning of the following symbols:

i the meaning of *m* is

.....

(*1 mark*)

ii the meaning of *z* is

.....

(*1 mark*)

b Chlorine consists of two naturally occurring isotopes. Information about these is given in Table 3.

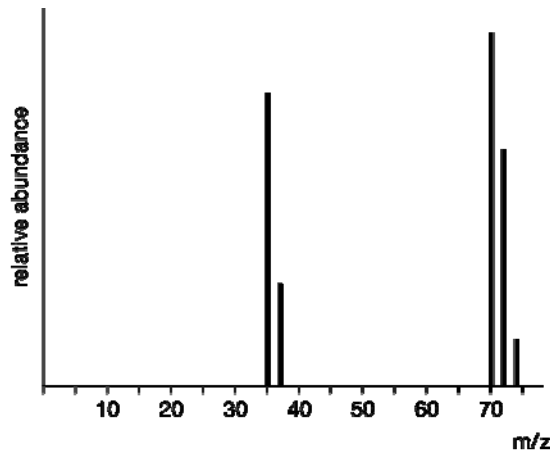
Table 3 *Relative isotopic mass and abundance of chlorine isotopes*

Isotope	Relative isotopic mass	Relative abundance
Chlorine-35	34.97	3
Chlorine-37	36.97	1

Calculate the relative atomic mass of chlorine. Give your answer to **two** decimal places.

Relative atomic mass = ... (*2 marks*)

c The following mass spectrum was recorded for a sample of **molecular** chlorine. The peak at *m*/*z* 70 corresponds to the molecular ion $^{35}Cl_2^+$.



Identify the particle responsible for each of the following peaks:

i Peak at *m*/*z* of 72.

.....

(*1 mark*)

ii Peak at *m*/*z* of 74.

.....

(*1 mark*)

iii Explain why the peak at *m*/*z* = 70 is higher than the peak at *m*/*z* = 74.

.....

.....

(*1 mark*)

4 Bicarbonate of soda, $NaHCO_3$, is commonly used as an ingredient when baking a cake. In the oven the bicarbonate of soda decomposes to produce carbon dioxide gas, which causes the cake mixture to rise.

a i What is the chemical name for bicarbonate of soda?

.....

(*1 mark*)

ii Construct an equation for the decomposition of solid bicarbonate of soda to form solid sodium carbonate, water, and carbon dioxide. Include state symbols.

.....

.....

.....

(*2 marks*)

iii Determine the relative formula mass of $NaHCO_3$.

.....

.....

(*1 mark*)

iv State whether the relative formula mass of $NaHCO_3$ is higher or lower than the relative formula mass of sodium carbonate.

.....

.....

(*1 mark*)

b Bicarbonate of soda also reacts with acid to form a salt, water, and carbon dioxide.

i Construct an equation for the reaction of bicarbonate of soda with hydrochloric acid, HCl.

.....

(*1 mark*)

ii Bicarbonate of soda loses its effectiveness if stored for long periods of time in a container that has not been closed properly. Suggest a reason for this.

.....

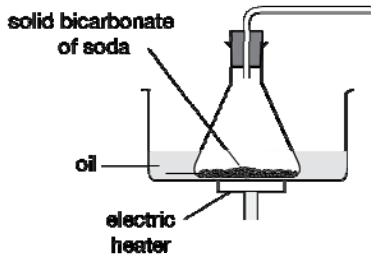
.....

(*1 mark*)

c You have been asked to carry out an experiment that would allow you to measure the volume of carbon dioxide gas released when half a teaspoon of bicarbonate of soda is heated to 110˚C.

i Complete the diagram below to show the apparatus set-up required for this experiment so that a volume of gas can be measured.

Label the apparatus you have drawn. (*2 marks*)



ii Suggest a reason for the use of an oil bath rather than a water bath.

Reason:

.....

.....

(*1 mark*)

iii State how you will know when the reaction has finished.

.....

.....

(*1 mark*)

iv Suggest an improvement to the method that would allow other scientists to replicate the results of this experiment.

.....

.....

(*1 mark*)

5 A sample of calcium is analysed in a mass spectrometer. It has been determined that the sample contains just two isotopes of calcium. The relative atomic mass of the calcium in the sample is 40.48. The sample contains 94.0% of calcium-40.

a Calculate the relative isotopic mass of the other calcium isotope in the sample. Show **all** your working.

Isotopic mass = ... (*3 marks*)

b Calcium is a silvery metal. When calcium reacts with pure, dry nitrogen gas, a solid compound forms.

i Name this solid compound.

.....

(*1 mark*)

ii Construct an equation for this reaction. Include state symbols.

.....

(*3 marks*)

c Calcium will react with cold water to make calcium hydroxide and a flammable gas.

i Construct an equation for this reaction.

.....

(*2 marks*)

ii Predict how the reaction rate would differ if strontium were used instead of calcium.

.....

.....

(*1 mark*)

d Magnesium is also a Group 2 metal. When magnesium reacts with steam, magnesium oxide and hydrogen gas are made.

i Construct an equation for this reaction.

.....

(*2 marks*)

ii A student safety sheet states that magnesium is highly flammable and burns very vigorously. It also states that water should not be used to extinguish a magnesium fire.

Using information from **d i**, suggest why a magnesium fire should not be extinguished using water.

.....

.....

(*1 mark*)

iii Suggest a safe way to extinguish a magnesium fire.

.....

.....

(*1 mark*)

e Car manufacturers are increasingly using magnesium to make car components rather than iron. Use a Periodic Table to suggest a reason for this.

.....

.....

(*1 mark*)

5 Electrons and bonding
Exam-style questions

1 An atom of sulfur contains 16 electrons. These electrons are arranged in shells, sub-shells, and orbitals.

a i Complete the electron configuration for an atom of sulfur:

$1s^2$..... (*1 mark*)

ii An atom of sulfur has 6 electrons in the third, outer shell. What is the maximum number of electrons that can be held in the third shell?

..... (*1 mark*)

b The electrons in sulfur are arranged into orbitals called s-orbitals and p-orbitals.

i Define *orbital*.

.....

..... (*1 mark*)

ii Describe the shape of an s-orbital.

.....

..... (*1 mark*)

iii Draw the shape of a p-orbital.

(*1 mark*)

2 Krypton is a noble gas found in Group 18 (0) of the Periodic Table.

a i Complete the full electron configuration of a krypton atom:

Kr: $1s^2$ ..... (*1 mark*)

ii Krypton is found in Period 4 of the Periodic Table. Explain how the electron configuration confirms this.

.....

..... (*1 mark*)

iii Identify which Group 2 metal ion will have the same electron configuration as an atom of krypton.

..... (*1 mark*)

b Krypton was once thought to be completely unreactive, but in 1963 a compound of krypton was made. This compound was called krypton difluoride, KrF_2.

i Suggest the oxidation state of Kr in KrF_2.

..... (*1 mark*)

ii Krypton difluoride is one of the most powerful oxidising agents known. Explain what the term oxidising agent means in terms of electron transfer.

.....

..... (*1 mark*)

3 A recent study has revealed that some mobile phone users are suffering skin irritations as a result of their handsets containing nickel or copper.

a In which block of the Periodic Table would you find nickel and copper?

..... (*1 mark*)

b The electron configuration for nickel is $[Ar]3d^84s^2$. A student has attempted the 'electrons in box' representation in Figure 1:

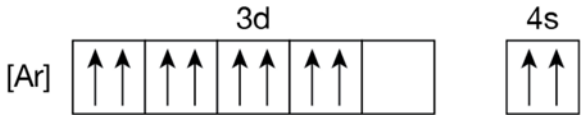


Figure 1 *Incorrect 'electrons in box' representation of nickel*

i What property of electrons is represented by the arrows?

..... (*1 mark*)

ii The 'electrons in box' representation for nickel shown in Figure 1 is incorrect. Identify the errors made and rewrite the correct representation in Figure 2:

Error 1: .....

.....

Error 2: .....

.....

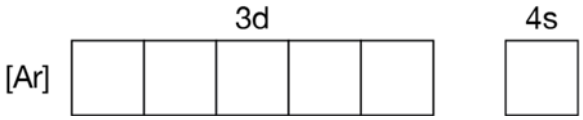


Figure 2 *Incomplete 'electrons in box' representation of nickel* (*3 marks*)

4 When potassium reacts with oxygen, an ionic compound, potassium oxide, is made.

a Construct an equation for this reaction.

..... (*1 mark*)

b **i** Describe what an *ionic bond* is.

.....

..... (*2 marks*)

ii Draw a '*dot-and-cross*' diagram to represent the bonding in potassium oxide.

(*2 marks*)

c The melting points of potassium oxide and calcium oxide are given in Table 1.

Table 1 *Melting points of some metal oxides*

Metal oxide	Melting point in K
Potassium oxide	1010
Calcium oxide	2886

What do these results suggest about the strength of the bonds in calcium oxide compared to potassium oxide? Suggest a reason for this.

.....

.....

..... (*2 marks*)

5 Propene is a useful alkene that can be burned as a fuel or polymerised into many different plastics. The molecular formula of propene is C_3H_6.

a Propene contains covalent bonds. Define what a *covalent bond* is.

.....

..... (*1 mark*)

b The bond enthalpies for the bonds in one molecule of propene are given in Table 2.

Table 2 *Bond enthalpies for bonds present in propene*

Bond	Bond enthalpy in kJ mol^{-1}
C–H	413
C–C	347
C=C	612

Use information in Table 2 to identify the strongest bond in propene. Suggest a reason why this is the strongest bond.

.....

..... (*2 marks*)

c Draw the '*dot-and-cross*' diagram for one molecule of propene.

(*2 marks*)

d When propene burns in a limited supply of oxygen, incomplete combustion takes place and carbon monoxide is produced along with water vapour. Carbon monoxide has a triple covalent bond, one of which is dative covalent. It is represented as shown in Figure 3.

Figure 3 *Bonding in carbon monoxide, CO*

i Construct an equation for the incomplete combustion of propene.

..... (*1 mark*)

ii How is a dative covalent bond different from a covalent bond?

.....

..... (*1 mark*)

iii State another name for a dative covalent bond.

..... (*1 mark*)

iv Draw the '*dot-and-cross*' diagram for a molecule of carbon monoxide.

(*2 marks*)

6 Carbon dioxide and silicon dioxide are both Group 14 (4) oxides but they have different structures and therefore different properties.

a Draw a '*dot-and-cross*' diagram for a molecule of carbon dioxide.

(*1 mark*)

b Carbon dioxide and silicon dioxide differ from each other in terms of both their structure **and** bonding. State the following to highlight these differences:

Structure of silicon dioxide: .....

Structure of carbon dioxide: .....

Bonding within silicon dioxide: .....

Bonding within carbon dioxide: ..... (*2 marks*)

c Another Group 14 (4) oxide has the formula PbO.

i Determine the oxidation number of lead in PbO and hence deduce the systematic name for PbO.

.....

.....

..... (*2 marks*)

ii Predict the structure and bonding in PbO.

.....

.....

..... (*2 marks*)

1 Lead(IV) oxide is made when lead reacts with oxygen according to the reaction shown in Equation 1.1.

$$Pb(s) + O_2(g) \rightarrow PbO_2(s) \quad \textit{Equation 1.1}$$

a **i** Identify, using oxidation numbers, the element that has been reduced.

.....

..... (*1 mark*)

ii Explain, in terms of electrons, what is meant by *reduction*.

.....

..... (*1 mark*)

b Lead(IV) oxide reacts with ice cold hydrochloric acid to produce lead(IV) chloride and water.

i Construct an equation for this reaction.

..... (*1 mark*)

ii If the reaction is done at higher temperatures, the lead(IV) chloride decomposes to give lead(II) chloride and chlorine. Write an equation for the decomposition of lead(IV) chloride.

..... (*1 mark*)

2 Two students are working together to prepare a 250 cm^3 standard solution of sodium carbonate. The method states:

- Using a balance accurate to **two** decimal places, weigh out approximately 1.3 g of anhydrous sodium carbonate accurately.
- Transfer to a small beaker and dissolve the powder in approximately 100 cm^3 of distilled water. Transfer this solution to a 250 cm^3 volumetric flask using a funnel.
- Make up to the mark using distilled water.

The students weighed the sodium carbonate and recorded the mass as 1.4 g.

a **i** Define the term anhydrous.

.....

..... (*1 mark*)

ii Identify the error that the students made in the weighing of the anhydrous sodium carbonate powder.

.....

..... (*1 mark*)

iii One of the students suggested dissolving the powder in 250 cm^3 of distilled water and then transferring this solution to the volumetric flask. He thought this modified method would save time. Identify the error within this modified method.

.....

..... (*1 mark*)

iv Suggest an improvement to the original method that would ensure that all of the powder weighed was transferred to the volumetric flask.

.....

..... (*1 mark*)

b Determine the mass, in grams, of sodium carbonate in 250 cm^3 of a 0.0520 mol dm^{-3} solution of sodium carbonate.

Mass of sodium carbonate = ... g (*2 marks*)

3 Hydrogen peroxide, H_2O_2, decomposes into water and oxygen when heated.

a **i** Construct an equation for this reaction.

..... (*1 mark*)

ii Deduce, by use of oxidation numbers, which element is reduced and oxidised in this reaction.

.....

.....

.....

..... (*3 marks*)

b Hydrogen peroxide, diluted with water, is used as a bleach. The concentration of the bleach can easily be determined by adding a suitable catalyst. The catalyst causes the hydrogen peroxide to quickly and completely decompose, and the volume of oxygen gas given off is measured.

i One suitable catalyst is potassium manganate(VII).

Deduce the chemical formula of potassium manganate(VII).

.....

(*1 mark*)

ii 5.00 cm^3 of hydrogen peroxide bleach released 74.4 cm^3 of oxygen gas. Under the experimental conditions used, 1 mole of gas molecules has a volume of 24.8 dm^3.

Calculate how many moles of oxygen gas were released.

.....

.....

(*1 mark*)

iii Using your answers to **a i** and **b ii**, determine how many moles of hydrogen peroxide were in the 5.00 cm^3 sample of bleach.

.....

.....

(*1 mark*)

iv Determine the concentration of hydrogen peroxide in the bleach in mol dm^{-3}.

.....

.....

(*1 mark*)

v According to the Health and Safety information, hydrogen peroxide solutions that are over 1.5 mol dm^{-3} but less than 2.3 mol dm^{-3} are classified as irritants.

Using your answer to part **iv**, explain whether this solution of bleach needs to be labelled as an irritant.

.....

.....

(*1 mark*)

4 20 cm^3 of a 0.050 mol dm^{-3} solution of H_xA reacts completely with 75 cm^3 of a 0.040 mol dm^{-3} solution of sodium hydroxide. The equation for the reaction is as follows:

$H_xA + xNaOH \rightarrow Na_xA + xH_2O$

a Calculate the value of x in H_xA.

Value of x = ... (*2 marks*)

b What mass of solid sodium hydroxide is required to make 250 cm^3 of a 0.040 mol dm^{-3} solution of sodium hydroxide?

Mass of sodium hydroxide = ... g (*2 marks*)

c Standard solutions of sodium hydroxide must be made up fresh when required. This is because carbon dioxide from the air dissolves in water and makes hydrogen carbonate, H_2CO_3, also known as carbonic acid.

i Explain, with an equation, how hydrogen carbonate affects the concentration of sodium hydroxide in solution.

.....

.....

.....

(*2 marks*)

ii Construct the ionic equation for this reaction. Include state symbols.

.....

(*1 mark*)

5 7.71 g of calcium carbonate was added to 40 cm^3 of 2.0 mol dm^{-3} hydrochloric acid.

a **i** Construct an equation for this reaction.

.....

(*1 mark*)

ii State whether this reaction is a redox reaction. Explain your answer in terms of oxidation states.

.....

.....

(*1 mark*)

iii Calculate the number of moles of each reactant to identify which reactant is in excess.

Reactant in excess = ... (*3 marks*)

b 0.5 dm^3 of concentrated hydrochloric acid (10.0 mol dm^{-3}) was spilt on the laboratory floor. Calculate the minimum mass of calcium carbonate that must be added to neutralise the spillage.

Mass of calcium carbonate = ... g (*2 marks*)

6 Vinegar is a solution of ethanoic acid, CH_3COOH. The concentration of ethanoic acid in some vinegar was determined by titrating it against a standard solution of sodium hydroxide.

25.0 cm^3 of vinegar was first transferred to a 250 cm^3 volumetric flask and made up to the mark with distilled water.

Then 25.0 cm^3 volumes of this diluted solution were titrated against 0.100 mol dm^{-3} sodium hydroxide.

The results are shown in Table 1.

Table 1 *Results of a titration between ethanoic acid and sodium hydroxide*

Titration	Rough	1	2	3
Final burette reading in cm^3	28.85	28.60	28.80	38.65
Initial burette reading in cm^3	0.05	0.10	0.05	10.05
Titre in cm^3	28.80	28.50	28.75	28.60

a i Select appropriate results and calculate the average titre.
Explain why you chose these results.

.....

.....

.....

.....

(*2 marks*)

ii Determine the number of moles of ethanoic acid in the 250 cm^3 volumetric flask. You can assume a 1:1 ratio of moles of ethanoic acid : sodium hydroxide.

Moles of ethanoic acid = ... (*2 marks*)

iii Use your answer to **ii** to determine the concentration of ethanoic acid in the original bottle of vinegar.

Concentration of ethanoic acid = ... (*1 mark*)

b The titration was repeated by another student who used a conical flask beneath her burette that was clean, but wet on the inside with distilled water used to rinse the flask.
Explain what effect, if any, using a wet rather than a dry conical flask will have on her titre value.

.....

.....

(*1 mark*)

c A supermarket own-brand of vinegar gave the concentration of ethanoic acid as 8.5×10^{-2} mol dm^{-3}.
Express this concentration in g dm^{-3}.

.....

.....

(*2 marks*)

d Ethanoic acid is a weak acid.
What is meant by a *weak acid*?

.....

.....

(*1 mark*)

3 Amount of substance
Exam-style questions

1 A popular children's breakfast cereal is 35% sugar. A recommended portion size is 30 g. This sugar is called sucrose and has a chemical formula of $C_{12}H_{22}O_{11}$.

a What mass of sugar is found in one portion of cereal?

.....

..... (*1 mark*)

b Determine the relative molecular mass of sucrose.

.....

..... (*1 mark*)

c How many moles of sugar are found in one portion of cereal?

.....

..... (*1 mark*)

d Calculate the number of sucrose molecules in one portion of cereal. Give your answer to **three** significant figures.

Number of sucrose molecules = ... (*1 mark*)

2 9.72 g of magnesium reacts completely with oxygen to produce magnesium oxide according to the following reaction:

$$2Mg + O_2 \rightarrow 2MgO \quad \textit{Reaction 2.1}$$

a **i** Calculate the number of moles of magnesium used.

Number of moles of magnesium = ... (*1 mark*)

ii Calculate the maximum mass of magnesium oxide that could be produced in this reaction.

Maximum mass of magnesium oxide = ... (*2 marks*)

iii The actual mass of magnesium oxide produced was 11.90 g. Calculate the percentage yield. Give your answer to **three** significant figures.

Percentage yield = ... % (*1 mark*)

b Magnesium oxide is also made by the following reaction:

$Mg + CuO \rightarrow MgO + Cu$ *Reaction 2.2*

i Determine the atom economy for the production of magnesium oxide using Reaction 2.2.

Atom economy = ... % (*1 mark*)

ii Which method of making magnesium oxide will have the higher atom economy out of Reaction 2.1 and Reaction 2.2? Explain your answer.

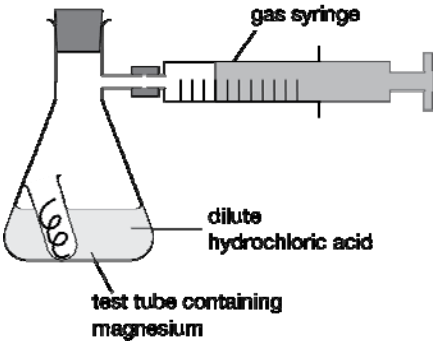
.....

..... (*1 mark*)

3 When magnesium reacts with acid the reaction is exothermic; it gives out heat. Magnesium reacts with hydrochloric acid according to the following reaction:

$Mg + 2HCl \rightarrow MgCl_2 + H_2$ Reac*tion 3.1*

The following apparatus was set up to measure the volume of gas evolved:



a 0.73 g of magnesium was added to excess hydrochloric acid.

i What is the purpose of having the magnesium inside the test tube within the conical flask?

.....

..... (*1 mark*)

ii Show that the amount of magnesium added was 0.030 moles.

(*1 mark*)

iii What is the maximum volume of hydrogen gas, measured at room temperature and pressure, that could be evolved from this experiment?

Volume of hydrogen gas = ... (*1 mark*)

iv The student recorded the actual volume of gas produced and it was slightly higher than expected. Suggest a reason for this, other than experimental error.

.....

.....

(*1 mark*)

b The experiment was repeated and 0.73 g of magnesium was added to 150 cm^3 of 0.50 mol dm^{-3} hydrochloric acid.

i Calculate the number of moles of hydrochloric acid added.

Moles of hydrochloric acid = ... (*1 mark*)

ii How many moles of acid were left unreacted in the conical flask?

Moles of hydrochloric acid = ... (*2 marks*)

iii The concentration of the hydrochloric acid used is 0.50 mol dm^{-3}. Express this concentration in g dm^{-3}. Give your answer to **three** significant figures.

Concentration of hydrochloric acid = ... g dm^{-3} (*2 marks*)

4 Phosphorus-containing matches were first made in the 1830s. They originally contained a form of phosphorus called white phosphorus, P_4, which is toxic and spontaneously ignites in air.

a The compound made when white phosphorus burns in oxygen was found to contain 43.7% by mass of phosphorus and 56.3% by mass of oxygen.

i Determine the empirical formula of this compound.

Empirical formula = ... (*2 marks*)

ii The relative molecular mass of this compound was determined to be 284 g mol^{-1}. Deduce the molecular formula of this compound.

Molecular formula = ... (*1 mark*)

b Another oxide of phosphorus has the molecular formula P_4O_6. This oxide is called phosphorus(III) oxide.

i What does the (III) in phosphorus(III) oxide signify?

..... (*1 mark*)

ii Write an equation for the reaction of white phosphorus, P_4, with oxygen to produce the solid compound P_4O_6. Include state symbols.

..... (*1 mark*)

c White phosphorus in matches was later replaced by another form of phosphorus called red phosphorus. Red phosphorus is non-toxic and stable at room temperature.

i Red phosphorus reacts with hydrogen to produce toxic phosphine gas, PH_3. Calculate the percentage by mass of phosphorus in phosphine. Give your answer to **three** significant figures.

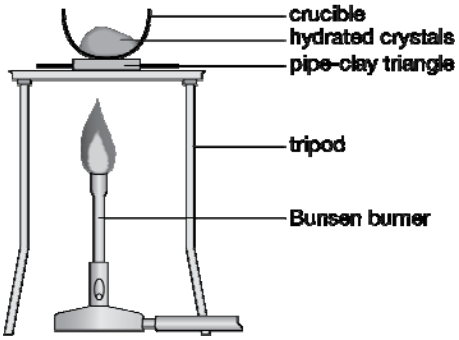
Percentage by mass = ... % (*1 mark*)

ii Phosphine gas can also be made by reacting white phosphorus with water. The products are phosphine gas and phosphoric acid, H_3PO_4. Construct an equation for this reaction.

.....

(*1 mark*)

5 Hydrated pink cobalt chloride crystals have the formula $CoCl_2.xH_2O$. An experiment was carried out to determine the value of x in the formula.



The pink crystals were heated in the crucible until all of the water of crystallisation had been removed. At this point the crystals were blue and anhydrous. The results in Table 1 were recorded:

Table 1 *Experimental results for determining the hydration of pink cobalt chloride*

	Mass in g
Mass of clean, dry, empty crucible	10.45
Mass of crucible and hydrated pink crystals	12.83
Mass of crucible and anhydrous blue crystals	11.75

a i The dot in the formula $CoCl_2 \cdot xH_2O$ separates the salt's formula from the water of crystallisation.
What is meant by 'water of crystallisation'?

.....

.....

(*1 mark*)

ii Determine the mass of water lost from the crystals.

Mass of water lost = ... (*1 mark*)

iii Determine x in the formula.

x = ... (*4 marks*)

iv Use your answer to part **iii** to find the relative formula mass of the hydrated crystals.

.....

.....

(*1 mark*)

b Suggest an extra step that could be added to the method that would allow you to know when *all* of the water of crystallisation has been removed.

.....

.....

(*1 mark*)

c A student followed the original method but noticed that when strongly heating their crystals some of them spat out of the crucible. Will this make their calculation of x too high or too low? Explain your answer.

.....

.....

.....

.....

(*3 marks*)

d Dilute cobalt chloride solution can be used as an invisible ink. The solution is very pale pink and so appears virtually colourless when written on paper. The ink is made visible by holding the paper over a hot light bulb.

Suggest the chemistry that makes this invisible ink visible again.

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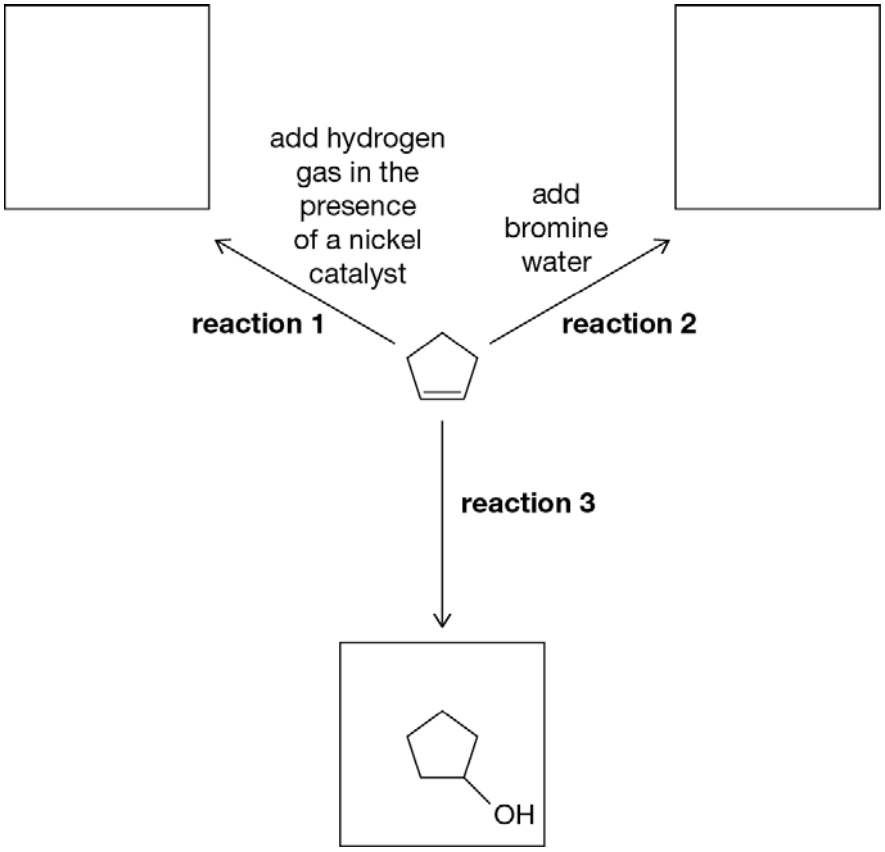
.....

(*2 marks*)

1 This question is about the reactions of cyclopentene, C_5H_{10}.



a Draw the skeletal formula of the product made from Reaction **1** and the main product from Reaction **2** in the boxes above. (*2 marks*)

b Give the reagents and conditions needed for Reaction **3** to take place.

.....

..... (*1 mark*)

c Name the product of Reaction **3**.

..... (*1 mark*)

d Reaction **2** demonstrates the test for unsaturation by the addition of bromine. State the colour change you would expect to observe during this reaction.

Colour change from _____ to _____ (*1 mark*)

e All three reactions above have an atom economy of 100%. Explain why.

.....

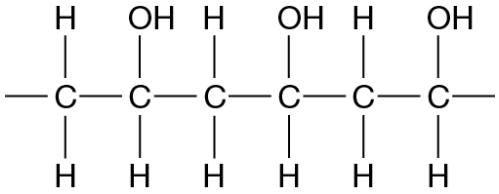
..... (*1 mark*)

2 Polybut-1-ene is a polymer that is insoluble in water. It is used for hot and cold water pipes and is made by the polymerisation of the monomer but-1-ene.

a Write an equation to show this polymerisation reaction.

(*2 marks*)

b Polymers that are soluble in water have been developed for use as plastic pouches to hold dishwasher liquid and laundry gels. A portion of one of these polymer chains is shown below:



i Suggest the monomer of this polymer.

(*1 mark*)

ii Suggest why this polymer is soluble, but polybut-1-ene is insoluble in water.

.....

.....

..... (*2 marks*)

3 One method for disposing of waste poly(alkenes) is by combustion, generating large amounts of heat.

a Give one possible advantage and one disadvantage to the environment of disposing of polymers in this way.

.....

.....

..... (*2 marks*)

b Halogenated plastics such as poly(vinyl chlorides), PVC, can produce toxic waste gases if combusted. One of these waste gases can be removed by a reaction with sodium hydrogencarbonate.
Name this waste gas.

..... (*1 mark*)

c New polymers are being developed that will break down more easily in the environment. One type is a biodegradable polymer.
Give an example of another type of degradable polymer and state what makes these polymers break down.

.....

.....

.....

(*2 marks*)

d Biodegradable polymers are often made from plant material and break down through microbial action to produce carbon dioxide and water. Manufacturers claim these types of polymers are carbon neutral.
Explain how the manufacturers can claim this and suggest why producing these polymers is actually unlikely to be carbon neutral overall.

.....

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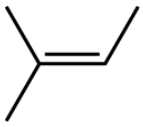
(*2 marks*)

4 The following alkene will undergo a reaction with hydrogen chloride to produce two possible products.



a Name the alkene.

.....

(*1 mark*)

b Name the type of mechanism for the reaction of this alkene with hydrogen chloride.

.....

(*2 marks*)

c Draw the mechanism for the reaction that will produce the **major** product.
Use curly arrows, partial charges and charges where relevant. (*4 marks*)

d Explain, using Markownikoff's rule, why this product is the major product.

.....

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.....

(*1 mark*)

e Name the minor product formed.

.....

(*1 mark)*

f Curly arrows can be used in mechanisms to show bond breaking. There are two types of bond breaking: homolytic and heterolytic.

Which type of bond breaking in shown in the mechanism drawn in part **c**?

Explain your answer.

.....

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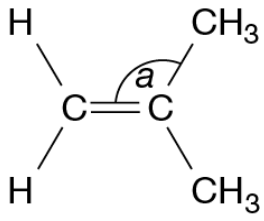
(*2 marks*)

5 The alkene methylpropene, shown below, is an unsaturated molecule that contains a C=C double bond.



a The C=C double bond is made up of a σ-bond and a π-bond.

Draw a diagram to show how a π-bond forms when two orbitals on the carbon atoms overlap. (*2 marks*)

b The bond angle, labelled *a*, in this molecule is 120°.

i What name is given to the shape around each carbon atom in this molecule?

.....

(*1 mark*)

ii Explain why this bond angle is 120°.

.....

.....

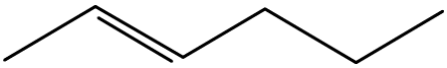
(*1 mark*)

c Despite having a C=C double bond, this molecule cannot demonstrate *E*/*Z* isomerism. Explain why.

.....

(*1 mark*)

d Hex-2-ene has a molecular formula of C_6H_{12}. The skeletal formula for *trans*-hex-2-ene is shown below:



i Draw the skeletal formula for *cis*-hex-2-ene.

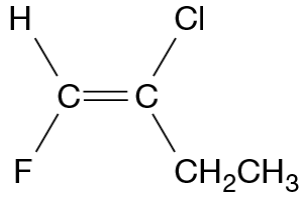
(*1 mark*)

ii There are other aliphatic alkenes, besides hex-2-ene, which also have a molecular formula of C_6H_{12}. Some of these alkenes can show *E*/*Z* stereoisomerism.

Draw the structures of two other **different** alkenes, both with a molecular formula C_6H_{12}, which can both show *E* and *Z* stereoisomers.

(*2 marks*)

e **i** Use the Cahn–Ingold–Prelog priority rules to identify whether the following structure is the *E* or *Z* stereoisomer. Explain your answer.



.....

.....

.....

(*2 marks*)

ii Why can this molecule **not** be labelled as either '*cis*' or '*trans*'?

.....

.....

(*1 mark*)

1 Graphene and graphite are both allotropes of carbon. They both contain single carbon–carbon covalent bonds.

a Give one other similarity between the structures of graphene and graphite and also one difference.

Similarity: .....

Difference: .....

(*2 marks*)

b Diamond is another allotrope of carbon but has a different structure from graphene and graphite.

i State the C–C–C bond angle in the following structures:

Graphene: .....

Diamond: .....

(*2 marks*)

ii Graphene and graphite are both good conductors of electricity. Explain, in terms of its structure, whether you would also expect diamond to be a good conductor of electricity.

.....

.....

..... (*1 mark*)

2 Mendeleev is considered to be the 'father' of the Periodic Table. He predicted the properties of unknown elements and left gaps for them in his table.

a Gallium was one of the elements that Mendeleev made predictions about.

Predict the structure and bonding of gallium based on its position in the Periodic Table.

.....

..... (*2 marks*)

b Explain whether you would expect gallium to be soluble or insoluble in water.

.....

..... (*1 mark*)

c Predict the formula of gallium oxide.

..... (*1 mark*)

d Predict the structure and bonding of gallium oxide.

.....

.....

..... (*2 marks*)

3 **a** Define the term *first ionisation energy*.

.....

.....

.....

.....

(*3 marks*)

b Write an equation, with state symbols, to show the reaction involved in the first ionisation energy of oxygen.

.....

(*1 mark*)

c Describe and explain the trend in the values of the first ionisation energies down Group 16 (6) from oxygen to polonium.

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.....

.....

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(*4 marks*)

d Oxygen is in Group 16 (6) of the Periodic Table.
How would its successive ionisation energies show this?
You may sketch a graph to illustrate your answer.

.....

.....

(*1 mark*)

4 Table 1 below shows the melting points of the elements across Period 3.

Table 1 *Melting points of some elements in Period 3*

Element	Na	Mg	Al	Si	P	S	Cl	Ar
Melting temperature in K	371	923	933	1683	317	392		84

a Explain, in terms of structure, why the melting points of Na, Mg, Al, and Si are all higher than those of P and S.

.....

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(*3 marks*)

b Explain, in terms of bonding, the following:

i Magnesium has a higher melting point than sodium.

.....

.....

.....

.....

(*3 marks*)

ii Phosphorus, P_4, has a lower melting point than sulfur, S_8.

.....

.....

.....

.....

(*3 marks*)

iii Predict the approximate melting point of chlorine.

.....

(*1 mark*)

c Describe the structure and bonding of aluminium. Include the names of the particles involved in the bonding within your answer.

.....

.....

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.....

(*3 marks*)

5 The graph in Figure 1 shows the variation of first ionisation energies across Period 2 of the Periodic Table.

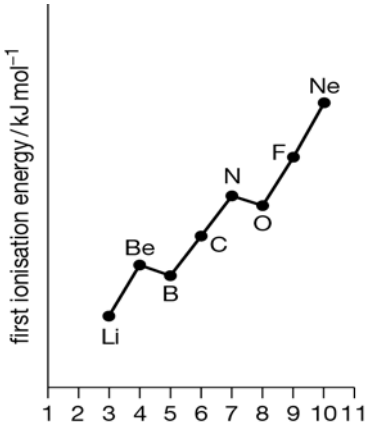

Figure 1 *First ionisation energies of some elements in Period 2*

a **i** Write the full electronic configuration for nitrogen.

.....

(*1 mark*)

ii Explain why the first ionisation energy of oxygen is lower than the first ionisation energy of nitrogen.

.....

.....

.....

(*2 marks*)

iii Explain why the first ionisation energy of nitrogen is higher than the first ionisation energy of carbon.

.....

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.....

(*3 marks*)

b The variation in first ionisation energies across a period of the Periodic Table provided evidence for what structures within an atom?

.....

(*1 mark*)

c Add to the graph in Figure 1 a cross to represent the predicted value of the first ionisation energy of sodium. Label your cross 'Na'. (*1 mark*)

d From the following elements: lithium, beryllium, and fluorine, predict which one will have the largest second ionisation energy. Explain your answer.

Prediction .....

Explanation .....

.....

.....

.....

(*3 marks*)

1 The Halogens are non-metallic elements found in Group 17 (7) of the Periodic Table.

a The Halogens have simple molecular structures and experience London forces between their molecules.

i Describe how these London forces arise. You may wish to draw a diagram.

.....

.....

.....

.....

..... (*3 marks*)

ii Describe and explain the trend in the boiling points of the Halogens as you descend the group.

.....

.....

.....

..... (*3 marks*)

b Explain why bromine, Br_2, has a lower boiling point than iodine monochloride, ICl, even though they have a similar relative molecular mass.

.....

.....

..... (*2 marks*)

2 Strontium is one of the Alkaline Earth Metals found in Group 2. Strontium compounds, such as strontium chloride, $SrCl_2$, are used in fireworks and emergency flares as they turn a flame crimson.

a i Write an equation to show how strontium chloride could be made by reacting strontium with an acid.

.....

.....

(*1 mark*)

ii Use oxidation states and your answer to **i** to show whether strontium is being oxidised or reduced when it reacts with this acid.

.....

.....

.....

.....

(*2 marks*)

b i Describe and explain the trend in first ionisation energy values as you move down Group 2.

.....

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(*3 marks*)

ii A student has incorrectly written an equation, shown below, to represent the second ionisation energy of strontium:

$$Sr(s) \rightarrow Sr^{2+}(aq) + e^-$$

Write the correct equation, including state symbols, which represents the second ionisation energy of strontium.

.....

.....

.....

(*1 mark*)

3 All Halogens are oxidising agents. Their relative strength is illustrated by a series of displacement reactions between the halogen and differing halide solutions.

a **i** In terms of electrons, what is meant by the term *oxidising agent*?

.....

..... (*1 mark*)

ii Describe and explain the trend in oxidising ability down Group 7.

.....

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.....

..... (*3 marks*)

b Bromine solution is added to two test tubes. Test tube 1 contains sodium chloride solution and test tube 2 contains sodium iodide solution. Then an equal volume of cyclohexane is added to both test tubes, which are then shaken and left to stand.

i A reaction occurs in just one of the test tubes. Write an ionic equation for the reaction that takes place.

..... (*1 mark*)

ii What colour would you observe in the organic, cyclohexane layer in each test tube?

Colour of organic layer in test tube 1: .....

Colour of organic layer in test tube 2: ..... (*1 mark*)

c Cyclohexane is a non-polar solvent. Halogens are soluble in non-polar solvents, since the halogens are non-polar molecules. Explain why the halogens are non-polar.

.....

.....

..... (*2 marks*)

4 Chlorine will react with cold, dilute sodium hydroxide solution as follows:

$$Cl_2(aq) + 2NaOH(aq) \rightarrow NaCl(aq) + NaClO(aq) + H_2O(l)$$

a **i** This reaction is an example of chlorine being both oxidised and reduced in the same reaction. What word is given to this type of reaction?

..... (*1 mark*)

ii Give the oxidation state of chlorine in the following species:

Cl_2 .....

NaCl .....

NaClO ..... (*2 marks*)

b When chlorine reacts with hot sodium hydroxide, the reaction produces $NaClO_3$ rather than NaClO.
The other products are the same as with cold NaOH(aq).

i Suggest the name for $NaClO_3$.

..... (*1 mark*)

ii Suggest the equation for this reaction.

..... (*1 mark*)

c Chlorine is a reactive and toxic gas. A student observes that damp universal indicator paper turns red and then white when chlorine gas comes into contact with it. The chlorine is reacting with the water in the indicator paper.
Write an equation for this reaction and use it to explain both colour changes.

.....

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.....

..... (*3 marks*)

5 Give the name of one aqueous reagent that could be added to distinguish between separate samples of the following pairs of chemicals. Write the expected observation in each case:

a AgBr(s) and AgI(s):

i Reagent ..... (*1 mark*)

ii Observation with AgBr(s)

..... (*1 mark*)

iii Observation with AgI(s)

..... (*1 mark*)

b $NaNO_3(aq)$ and $Na_2SO_4(aq)$:

i Reagent ..... (*1 mark*)

ii Observation with $NaNO_3(aq)$

..... (*1 mark*)

iii Observation with $Na_2SO_4(aq)$

..... (*1 mark*)

c An excess of silver nitrate solution was added to 10.0 cm^3 of sodium chloride solution, and 0.717 g of silver chloride was precipitated.

i Write an ionic equation, including state symbols, for this reaction.

..... (*2 marks*)

ii Calculate the concentration of the sodium chloride solution in mol dm^{-3}.

Concentration = ... (*2 marks*)

6 Shapes of molecules and intermolecular forces Exam-style questions

1 Tetrachloromethane, CCl_4, is a liquid at room temperature.

a Draw a diagram to show the 3-dimensional shape of a molecule of tetrachloromethane and predict the value of the Cl–C–Cl bond angle.

(*2 marks*)

b Each C–Cl bond within this molecule is polar. Why is this?

.....

.....

..... (*2 marks*)

c Explain why the tetrachloromethane molecule has no overall dipole.

.....

..... (*1 mark*)

d Tetrachloromethane is used as a solvent (e.g., in dry cleaning).

Predict, with a reason, whether you would expect the following molecules to be soluble in tetrachloromethane:

Iodine, I_2

.....

.....

Sodium chloride, NaCl

.....

.....

(*2 marks*)

6 Shapes of molecules and intermolecular forces Exam-style questions

2 Phosphine, PH_3, is a hydride of the Group 15 (5) element phosphorus.

a **i** Draw a 'dot-and-cross' diagram of a phosphine molecule. You need only include the outer shell electrons.

(*1 mark*)

ii Suggest, with reasons, the shape of a phosphine molecule and predict the bond angles.

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.....

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..... (*3 marks*)

b Ammonia, NH_3, is another Group 15 (5) hydride.
Predict, with reasons, whether ammonia will have a higher or lower boiling point than phosphine.

.....

.....

..... (*2 marks*)

6 Shapes of molecules and intermolecular forces Exam-style questions

3 Paperclips are made from steel and the density of steel is around 8 g cm^{-3}. The density of water is 1 g cm^{-3}, so you would expect the paperclip to sink in water. However, if lowered carefully onto the surface of the water, the paperclip will float. This is because water has a high surface tension.

a Using your knowledge of the properties of water, suggest why water has a high surface tension.

.....

.....

(*1 mark*)

b When a drop of liquid soap is added to the water, the paperclip sinks. Suggest why.

.....

.....

(*1 mark*)

c Draw a diagram to show the intermolecular interaction between two molecules of water. Include relevant dipoles and lone pairs of electrons.

(*2 marks*)

6 Shapes of molecules and intermolecular forces Exam-style questions

4 The halogen iodine, I_2, is a solid at room temperature. A spatula full of iodine crystals was placed in a conical flask. The conical flask was warmed very gently until a purple vapour began to fill the flask, at which point the stopper was added.

a i Explain how the structure and bonding in iodine accounts for its relatively low boiling point.

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(*3 marks*)

ii Would you expect astatine, another halogen, to have a higher or lower boiling point than iodine? Explain your answer.

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(*2 marks*)

b Iodine vapour will react with hot sodium to produce sodium iodide.

i Write an equation for this reaction.

.....

(*1 mark*)

ii Describe the bonding and structure in sodium iodide.

.....

.....

.....

(*2 marks*)

iii Select, from the table below, the letter that best shows the expected properties of sodium iodide: (*1 mark*)

Letter	Solubility in water	Melting point	Electrical conductivity
A	High	Low	Good when solid, good when molten
B	Low	High	Poor when solid, good when molten
C	Low	Low	Good when solid, poor when molten
D	High	High	Poor when solid, good when molten

c Draw 'dot-and-cross' diagrams for both iodine and sodium iodide. You only need to show the outer electrons.

(*3 marks*)

Wider reading to support your studies in Chemistry

Title	Author/Contributor	Topic
Why Chemical Reactions Occur	James Keeler	Chemical Reactions
The Disappearing Spoon and Other Extraordinary True Tales from the Periodic Table	Sam Kean	Periodic Table
Chemical curiosities: spectacular experiments and inspired quotes	Roesky, Herbert W. & Möckel, Klaus	Chemical Reactions and Practical Skills
Uncle Tungsten – memories of a chemical boyhood	Oliver Sacks	Periodic Table
The facts of life	Caroline M. Pond	Organic Chemistry
Magic molecules – how drugs work	Susan Aldridge	Organic Chemistry and linked to Biology

Useful websites to support your studies in Chemistry

Website	Website Link	Topic
Physics and Maths Tutor	https://www.physicsandmathstutor.com/past-papers/a-level-chemistry/	Chemistry – All modules
Royal Society of Chemistry	https://edu.rsc.org/student	Chemistry – All modules
Knockhardy notes	http://www.knockhardy.org.uk/sci.htm	Chemistry – All modules
The Royal Society	http://royalsociety.org	All
The Scientific journal	http://nature.com	All
Nobel prize	http://nobelprize.org	All