Higher Level Chemistry Exam Questions By Topic 2004 -2009

2009 Question 4 (j)

Identify the chemical hazard associated with each of the following warning symbols.

(*i*) 

(*ii*) 

The Atom

2004 Question 4 (a)

Define *relative atomic mass*.

2004 Question 10 (b)

Describe how Bohr used line emission spectra to explain the existence of energy levels in atoms. (13)
(*i*) Why does each element have a unique line emission spectrum? (6)
(*ii*) The fact that each element has a unique line spectrum forms the basis for an instrumental technique which can be used to detect heavy metals and to measure their concentrations in a soil or a water sample. Name the instrumental technique. (3)
(*iii*) Bohr's atomic theory was later modified. Give **one** reason why this theory was updated. (3)

2006 question 4 (b)

Name the scientist, shown in the photograph, who identified cathode rays as subatomic particles.

2007 Question 11 (a)

(*a*) In 1910 Rutherford (pictured right) and his co-workers carried out an experiment in which thin sheets of gold foil were bombarded with alpha particles. The observations made during the experiment led to the discovery of the atomic nucleus.
(*i*) Describe the model of atomic structure which existed immediately *prior* to this experiment. (7)
(*ii*) In this experiment it was observed that most of the alpha particles went straight through the gold foil. Two other observations were made. State these other observations and explain how each helped Rutherford deduce that the atom has a nucleus. (12)

2008 Question 4 (d)

Name the type of spectroscopy, based on absorptions within

a particular range of electromagnetic frequencies, and used as a 'fingerprinting' technique to identify organic and inorganic compounds.

2009 Question 4 (a)

The scientist pictured on the right used charged oil drops to determine the size of the charge on a sub-atomic particle. Name the scientist, and the sub-atomic particle involved in his experiments.

Arrangement of Electrons in the Atom

2004 Question 5 (a)

Write the electron configuration (*s, p,* etc.) of the nitrogen atom. (5)

2005 Question 4 (c) + (e)

Name the series of coloured lines in the line emission spectrum of hydrogen corresponding to transitions of electrons from higher energy levels to the second (n = 2) energy level.

Distinguish between an *atomic orbital* and a *sub-level*.

2006 Question 4 (a)

Write the electron configuration (*s, p, etc.*) of a chromium atom in its ground state.

2006 Question 5 (a)

(*i*) Describe how you would carry out a flame test on a sample of potassium chloride. (8)

(*ii*) Why do different elements have unique atomic spectra? (6)

(*iii*) What instrumental technique is based on the fact that each element has unique atomic spectra? (3)

Bohr's model of the atom explained the existence of energy levels on the basis of atomic spectra. Bohr's theory was later modified to incorporate the idea of *orbitals* in recognition of the wave nature of the electron and Heisenberg's uncertainty principle.

(*iv*) Define *atomic orbital*. (6)
(*v*) What does Heisenberg's uncertainty principle say about an electron in an atom? (6)

2006 Question 10 (a)

(*i*) What are *isotopes*? (4)
(*ii*) Define *relative atomic mass*, $\boldsymbol{A}_r$. (6)
(*iii*) What is the principle on which the mass spectrometer is based? (9)
(*iv*) Calculate the relative atomic mass of a sample of lithium, given that a mass spectrometer shows that it consists of 7.4 % of $_6$Li and 92.6 % of $_7$Li. (6)

2007 Question 5 (a)

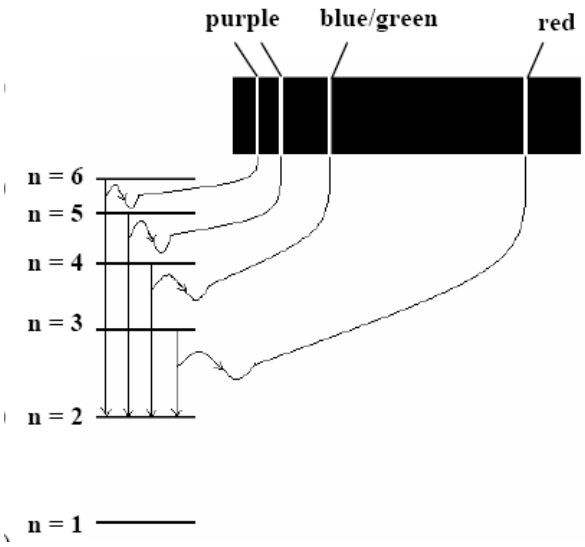
Define *energy level*. (5)
Write the electron configuration (*s*, *p*) for the sulfur atom in its ground state, showing the arrangement in atomic orbitals of the highest energy electrons. (6)
State how many (*i*) energy levels, (*ii*) orbitals, are occupied in a sulfur atom in its ground state. (6)

2008 Question 4 (a)

Write the electron configuration (*s, p, etc.*) of the aluminium ion (Al^{3+}).

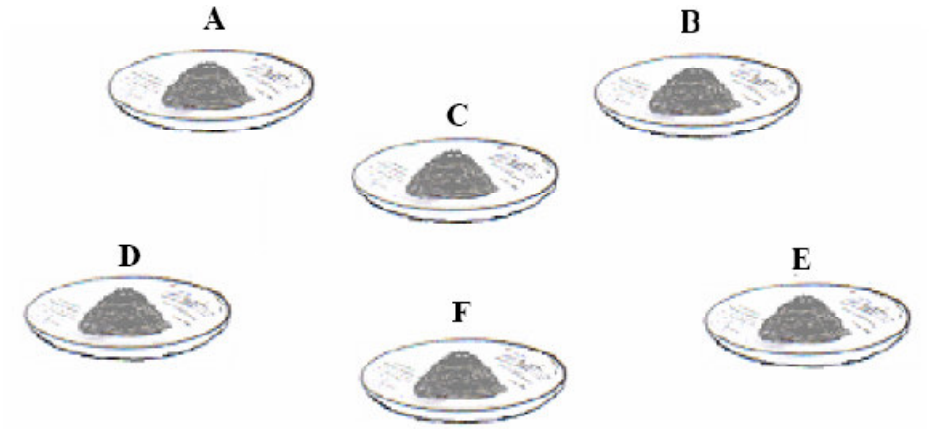
2008 Question 10 (c)

(*i*) Define *energy level*. (4)
(*ii*) Distinguish between *ground state* and *excited state* for the electron in a hydrogen atom. (6)
The diagram shows how Bohr related the lines in the hydrogen emission spectrum to the existence of atomic energy levels.
(*iii*) Name the series of lines in the visible part of the line emission spectrum of hydrogen. (3)
(*iv*) Explain how the expression $E_2 - E_1 = hf$ links the occurrence of the visible lines in the hydrogen spectrum to energy levels in a hydrogen atom. (12)



2009 Q3

The clock glasses shown in the diagram contained pure samples of the following salts: **KCl**, **KNO_3**, **$Na_2HPO_4.12H_2O$**, **$Na_2SO_3.7H_2O$** , **$NaHCO_3$** and **$Na_2SO_4.10H_2O$**. Each clock glass (**A – F**) contained a different salt. A student was provided with standard laboratory apparatus and reagents, and was asked to identify the six salts.



(*a*) Describe how the student could have distinguished between the samples that contained potassium ions and those that contained sodium ions using the flame test technique. (11)

2009 Question 4 (b)

State the *Heisenberg uncertainty principle*.

2009 Question 5(d)

(*d*) Write the *s*, *p* electron configuration for the potassium atom.
Hence state how many (*i*) energy sub-levels, (*ii*) individual orbitals, are occupied by electrons in a potassium atom.
Explain why there are electrons in the fourth main energy level of potassium although the third main energy level is incomplete. (12)

2009 Question 10(c)

In 1922, Francis Aston, pictured right, was awarded the Nobel Prize in chemistry for detecting the existence of isotopes using the first mass spectrometer.
(*i*) What are isotopes? (7)
(*ii*) What is the principle of the mass spectrometer? (9)
(*iii*) Calculate, to two decimal places, the relative atomic mass of a sample of neon shown by mass spectrometer to be composed of 90.50% of neon–20 and 9.50% of neon–22. (9)

The Periodic Table

2005 Question 4 (d)

What contribution did Dobereiner make to the systematic arrangement of the elements?

2006 Question 4 (f)

What contribution did Newlands make to the systematic arrangement of the elements known to him?

2008 Question 4 (b)

What contribution did Henry Moseley, the scientist shown in the photograph, make to the systematic arrangement of the elements in the periodic table?

Chemical bonding and Chemical Formulas

2004 Question 5 (a)

Show, using dot and cross diagrams, the bond formation in a nitrogen molecule.

Describe the bonding in the nitrogen molecule in terms of sigma (σ) and pi (π) bonding. (9)
What type of intermolecular forces would you expect to find in nitrogen gas? Explain your answer. (6)

2005 Question 4 (a) + (b)

Define *electronegativity*.

What are the possible shapes for molecules of general formula $\mathbf{AB_2}$?

2005 Question 5 (c)

(*c*) Define *covalent bond*. (6)

Distinguish between a sigma (σ) and a pi (π) covalent bond. (6)

2004 Question 4 (b) + (c)

Account for the difference in the shapes of the ammonia ($\mathbf{NH_3}$) and boron trifluoride ($\mathbf{BF_3}$) molecules.

The boiling points of hydrogen and oxygen are 20.0 K and 90.2 K respectively. Account for the higher boiling point of oxygen.

2004 Question 3

A sample of impure benzoic acid was recrystallised as follows: 2.5 g of the impure benzoic acid was weighed out and dissolved in the minimum amount of hot water. The hot solution was filtered and the filtrate was allowed to cool and recrystallise. The recrystallised benzoic acid was isolated by filtration. After drying, 2.25 g of purified acid were obtained.

*(*i) Why is it important to use the minimum amount of hot water in the procedure? (5)

(*ii*) Indicate clearly the stage of the recrystallisation procedure at which *insoluble* impurities were removed and how their removal was achieved. Indicate also the stage at which *soluble* impurities were removed and how their removal was achieved. (12)

(*iii*) How could you have ensured that the recrystallisation was complete? (3)

(*iv*) How could the crystals have been dried? (3)

(*v*) What was the percentage yield of purified benzoic acid? (3)

(*b*) Melting points of samples of the impure and recrystallised benzoic acid were taken and compared.

*(*i) Describe with the aid of a labelled diagram how you would have measured the melting point of one of these samples. (15)

(*ii*) Give **two** ways in which you would expect the melting point of the impure benzoic acid to differ from that of the purified acid. (6)

(*iii*) State **one** use of benzoic acid and its salts. (3)

2006 question 4 (c)

Under what circumstances can ionic compounds conduct electricity?

2007 Question 4 (c)

Distinguish between sigma (σ) and pi (π) covalent bonding.

2007 Question 5 (b) + (c)

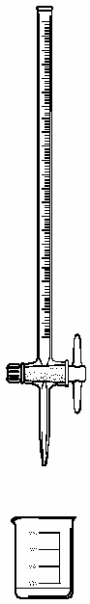
(b) Use electronegativity values (Mathematical Tables p 46) to predict the type of bond expected between hydrogen and sulfur.
Write the chemical formula for hydrogen sulfide.
Use clear dot and cross diagrams to show the bonding in hydrogen sulfide. (15)
Would you expect the hydrogen sulfide molecule to be *linear* or *non-linear* in shape?
Justify your answer. (6)

(*c*) Hydrogen sulfide has a boiling point of 212.3 K and water has a boiling point of 373 K.
Account for the difference in the boiling points of these substances. (6)
Would you expect hydrogen sulfide to be soluble in water? Explain your answer. (6)

2008 Question 4 (g)

Account for the difference in bond angle between water (104.5 º) and methane (109.5 º).

2008 Question 5 (c), (d), (e) and (g)



(*c*) Use electronegativity values to predict the types of bonding (*i*) in water, (*ii*) in methane, (*iii*) in magnesium chloride. (9)
(*d*) Use dot and cross diagrams to show the formation of bonds in magnesium chloride. (6)
(*e*) Explain the term *intermolecular forces*. (6)
(*f*) Use your knowledge of intermolecular forces to explain why methane has a very low boiling point (b.p. = –164 ºC).
The relative molecular mass of methane is only slightly lower than that of water but the boiling point of water is much higher (b.p. = 100 ºC). Suggest a reason for this. (6)
(*g*) The diagram shows a thin stream of liquid flowing from a burette. A stream of water is deflected towards a positively charged rod whereas a stream of cyclohexane is undeflected. Account for these observations
Explain what would happen in the case of the stream of water if the positively charged rod were replaced by a negatively charged rod. (9)

2009 Question 4(d)

Define *bond energy*.

2009 Question 11(b)

(*i*) Use a dot and cross diagram to show the bonding in an ammonia, **NH_3**, molecule. (7)
(*ii*) Use electron pair repulsion theory to determine the shape of the ammonia molecule. Explain clearly why the bond angle in ammonia is only 107°. (9)
(*iii*) Hydrogen bonding occurs between ammonia molecules. What are *hydrogen bonds*? Draw a diagram illustrating hydrogen bonding in ammonia. (9)

Equations and tests for Anions

2004 Question 4 (j)

How could the presence of sulfite ions in aqueous solution be detected?

2005 Question 4 (f)

How could you confirm the presence of nitrate ions in an aqueous solution?

2007 Question 4 (f)

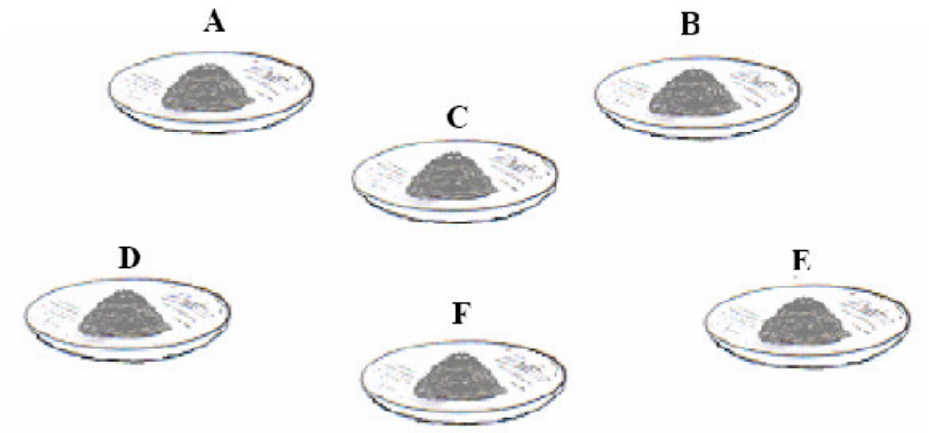
Name the two reagents used in the brown ring test for the nitrate ion.

2008 Question 10 (a) (iii)

Describe a test to confirm the presence of the chloride ion in aqueous solution. (7)

2009 Q3

The clock glasses shown in the diagram contained pure samples of the following salts: **KCl**, **KNO_3**, **$Na_2HPO_4.12H_2O$**, **$Na_2SO_3.7H_2O$** , **$NaHCO_3$** and **$Na_2SO_4.10H_2O$**. Each clock glass (**A – F**) contained a different salt. A student was provided with standard laboratory apparatus and reagents, and was asked to identify the six salts.



(*b*) Which of the substances listed above was identified by the addition of silver nitrate, **$AgNO_3$**, solution to a solution of each sample in turn? What observation indicated a positive test result? (6)

(*c*) One of the samples gave a brown ring when a little concentrated sulfuric acid was carefully poured down the inside of a slanting test tube which contained a solution of the salt, together with another reagent. What was the other reagent? Which salt was identifiable by the appearance of a brown ring? (6)

(*d*) Describe how you would test the samples for the presence of the phosphate anion. (9)

(*e*) Having completed the tests referred to in (*a*) – (*d*) above the student should have positively identified

three of the salts. A solution of barium chloride, **$BaCl_2$**, was then added to solutions of each of the three remaining samples in turn. A white precipitate was produced in two cases. Write a balanced equation for either **one** of the two reactions that occurred.

The student then added dilute hydrochloric acid to the precipitates.

What would the student have observed and what conclusion should have been drawn regarding the identities of the two salts? (12)

(*f*) The student was able to identify the last salt by a process of elimination. Suggest a way of confirming the identity of this salt. (6)

Trends in the Periodic Table

2004 Question 5 (b)

Define *first ionisation energy*. (9)

There is a general increase in first ionisation energy across a period of the periodic table.
State the **two** principal reasons for this trend. (6)

The table shows the first and second ionisation energies of nitrogen, oxygen, neon and sodium.
Account for the decrease in first ionisation energy between nitrogen and oxygen.
Explain why the second ionisation energy of sodium is significantly (about nine times) higher than the first while the increase in the second ionisation energy of neon compared to its first is relatively small (less than twice the first). (15)

Element	First ionisation energy (kJ mol^{-1})	Second ionisation energy (kJ mol^{-1})
Nitrogen	1400	2860
Oxygen	1310	3390
Neon	2080	3350
Sodium	494	4560

2005 Question 5 (b)

(*b*) Define *atomic radius* (*covalent radius*). (6)

Describe and account for the trend in atomic radii (covalent radii) of the elements
(i) across the second period, (ii) down any group, of the periodic table. (15)

2005 Question 10 (b)

The minimum energy required to completely remove the most loosely bound electron from a mole of gaseous atoms in their ground state defines an important property of every element.
(*i*) Identify the energy quantity defined above. State the unit used to measure this quantity. (7)
(*ii*) Using **X** to represent an element, express the definition above in the form of a balanced chemical equation. (6)
(*iii*) Would it take more or less energy to remove the most loosely bound electron from an atom if that electron were not in its ground state? Explain. (6)
(*iv*) An element has a low first ionisation energy value and a low electronegativity value. What does this information tell you about how reactive the element is likely to be, and what is likely to happen to the atoms of the element when they react? (6)

2006 Question 5 (b)

(*i*) Define *electronegativity*. (6)
(*ii*) Explain why there is a general increase in electronegativity values across the periods in the periodic table of the elements. (6)
(*iii*) Explain, in terms of the structures of the atoms, the trend in reactivity down Group I (the alkali metal group) of the periodic table. (9)

2007 Question 4 (a)

Define *atomic (covalent) radius*.

2008 Question 5 (a) + (b)

(*a*) Define *electronegativity*. (5)
(*b*) State and explain the trend in electronegativity values down the first group in the periodic table of the elements. (9)

2009 Question 5 (a), (b) + (c)

(*a*) Define *first ionisation energy* of an element. (8)
(*b*) Use the values on page 45 of the Mathematics Tables to plot a graph on graph paper of first Ionization energy *versus* atomic number for the elements with atomic numbers from 10 to 20 inclusive. (12)
(*c*) Account fully for
(*i*) the general increase in ionisation energy values across the third period of the Periodic Table,
(*ii*) the peaks which occur in your graph at elements 12 and 15,
(*iii*) the sharp decrease in ionisation energy value between elements 18 and 19. (18)

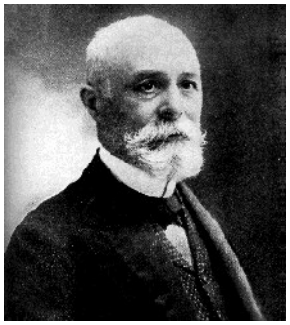
Radioactivity

2004 Question 11 (a)

(*a*) Define radioactivity. (6)
(*i*) State **two** properties of beta (β) particles. (6)
(*ii*) Write an equation for the nuclear reaction involved in the beta decay of $_{14}C$ (carbon-14). (6)
(*iii*) Explain how the carbon-14 isotope allows certain archaeological discoveries to be dated. (7)

2005 Question 5 (a)

*(*a) What are *isotopes*? (5)



Name the scientist pictured on the right who is credited with the discovery in 1896 that uranium salts emit radiation. (3)

Give an example of a radioactive isotope and state **one** common use made of this isotope. (9)

2006 Question 4 (c)

Give **two** differences between a nuclear reaction and a chemical reaction.

2007 Question 11 (a)

In November 2006 former Soviet agent, Alexander Litvinenko, died in London. The cause of his death was identified as radiation poisoning by polonium-210.
(*iii*) Polonium-210 decays emitting an alpha particle.
Copy and complete the equation for the alpha-decay of polonium-210, filling in the values of ***x*** (atomic number), ***y*** (mass number) and **Z** (elemental symbol). (6)

$$^{210}_{84}Po \longrightarrow {}^{y}_{x}Z \quad + \quad {}^{4}_{2}He$$

2008 Question 4 (c)

Give **two** properties of alpha particles.

2009 Question 4(b)

What change occurs in the nucleus of an atom when it undergoes beta emission?

The Mole Concept

Properties of Gases

2004 Question 4 (d)

State *Charles' law*.

2004 Question 10 (c)

State *Avogadro's law*. (5)
(*i*) What is an ideal gas? (5)
(*ii*) State **one** reason why ammonia gas deviates from ideal gas behaviour. (3)
(*iii*) A small quantity of the volatile organic solvent propanone (**C_3H_6O**) evaporates at room temperature and pressure. Use the equation of state for an ideal gas to calculate the volume, in litres, of propanone vapour formed when 0.29 g of liquid propanone evaporates taking room temperature as 20 ºC and room pressure as 101 kPa. (12)

2005 Question 11 (b)

(*i*) Define *a mole of a substance*. (7)

(*ii*) State *Avogadro's law*. (6)

(*iii*) A foil balloon has a capacity of 10 litres. How many atoms of helium occupy this balloon when it is filled with a 10% (v/v) mixture of helium in air at room temperature and pressure? (12)

2006 Question 11 (a)

(*i*) What is an *ideal gas*? (4)
(*ii*) Give **one** reason why a real gas like carbon dioxide deviates from ideal behaviour. (3)
(*iii*) Assuming ideal behaviour, how many moles of carbon dioxide are present in 720 cm^3 of the gas at 10 ºC and a pressure of 1×10^5 Pa? Give your answer correct to one significant figure. (9)
(*iv*) How many molecules of carbon dioxide are present in this quantity of carbon dioxide? (3)
(*v*) The reaction between carbon dioxide and limewater is represented by the following balanced equation.

$$Ca(OH)_2 + CO_2 \longrightarrow CaCO_3 + H_2O$$

What mass of calcium hydroxide is required to react completely with the quantity of carbon dioxide gas given in (*iii*) above? (6)

2007 Question 10 (b)

(*i*) State *Avogadro's law*. (7)
(*ii*) Carbon dioxide is stored under pressure in liquid form in a fire extinguisher.
Two kilograms of carbon dioxide are released into the air as a gas on the discharge of the fire extinguisher. What volume does this gas occupy at a pressure of 1.01×10^5 Pa and a temperature of 290 K? (9)
What mass of helium gas would occupy the same volume at the same temperature

and pressure? (6)
(*iii*) Give **one** reason why carbon dioxide is more easily liquefied than helium. (3)

2009 Question 10(a)

(*a*) State *Avogadro's law*. (7)
Give **two** assumptions of the kinetic theory of gases. (6)
Give **two** reasons why real gases deviate from ideal gas behaviour. (6)
How many moles of gas are present in a sample containing 1.8×10^{24} atoms of chlorine at s.t.p.? (6)

Stoichiometry

2004 Question 4 (h)

What is the percentage by mass of iron in iron(III) oxide (**Fe_2O_3**)?

2004 Question 10 (a)

Hydrochloric acid is severely corrosive to skin and eyes and toxic by inhalation or ingestion. It should be handled carefully and stored safely.

The entire contents of a bottle containing 2.5 litres of concentrated hydrochloric acid were accidentally spilled in a laboratory. The spilled acid was neutralised by adding solid powdered sodium carbonate. The neutralisation reaction is described by the following equation.

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + H_2O + CO_2$$

The spilled acid was a 36% (w/v) solution of hydrogen chloride in water.
(*i*) Calculate the number of moles of hydrochloric acid spilled. (10)
(*ii*) What was the minimum mass of anhydrous sodium carbonate required to completely neutralise all of the spilled hydrochloric acid? (9)
(*iii*) What volume of carbon dioxide in litres, at room temperature and pressure, was produced in this neutralisation reaction? (6)

2005 Question 4 (h)

When 3.175 g of copper reacts with chlorine gas 6.725 g of copper chloride is formed.
Find by calculation the empirical formula of the chloride.

2005 question 10 (a)

(*a*) An indigestion tablet contains a mass of 0.30 g of magnesium hydroxide [**$Mg(OH)_2$**] as its only basic ingredient. The balanced chemical equation for the reaction between magnesium hydroxide and hydrochloric acid (**$HCl_{(aq)}$**), the acid produced in the stomach, is as follows:

$$Mg(OH)_2 + 2HCl \longrightarrow MgCl_2 + 2H_2O$$

(*i*) Calculate the volume of 1.0 M **HCl** neutralised by two of these indigestion tablets.
Give your answer correct to the nearest cm^3. (8)
(*ii*) What mass of salt is formed in this neutralisation? (5)
(*iii*) How many magnesium ions are present in this amount of the salt? (6)
(*iv*) Another indigestion remedy consists of a suspension of magnesium hydroxide [**$Mg(OH)_2$**] in water and is marked 6% (w/v).
What volume of this second indigestion remedy would have the same neutralising effect on stomach acid as two of the indigestion tablets mentioned earlier? (6)

2006 Question 4 (d)

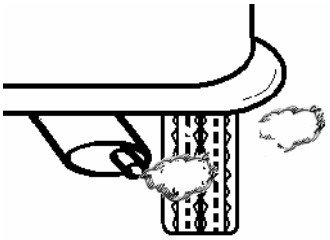
Calculate the percentage carbon, by mass, in methylbenzene.

2007 Question 4 (e) + (h)

How many iron atoms should be consumed daily to meet the recommended daily intake of iron in the diet of 0.014 g?

A 500 cm^3 can of beer contains 21.5 cm^3 of ethanol. Calculate its % alcohol, i.e. the concentration of alcohol in the beer as a % (v/v).

2008 Question 11 (b)



From July 2008 changes will apply to the way in which taxes are levied on new cars bought in Ireland. Vehicles that, in controlled tests, have higher levels of carbon dioxide emission per kilometre travelled will be subject to higher levels of taxation. The measures are designed to encourage the purchase of cars that are more fuel-efficient and have lower CO_2 emissions. The manufacturer's specification for a certain diesel-engined car is 143 g CO_2 / km (i.e. the car produces 143 g of CO_2 for every kilometre travelled).
The car is used for morning and afternoon school runs totalling 8 km per day.
Use the manufacturer's CO_2 emission figure to calculate the amount of CO_2 produced each day during the school runs in terms of

(*i*) the mass of CO_2, (*ii*) the number of moles of CO_2,
(*iii*) the volume of CO_2 at room temperature and pressure. (18)

If a large SUV (sports utility vehicle) with a CO_2 emission rating of 264 g CO_2 / km were used instead of the car mentioned above, how many more litres of CO_2 would be released into the atmosphere per day during the school runs? (7)

Acids + Bases

2004 Question 4 (e)

Write (*i*) the conjugate acid and (*ii*) the conjugate base of HPO_4^{2-}

2005 Question 8 (a) + (b)

(a) Define (i) *acid*, (ii) *base*, according to the Brønsted-Lowry theory. (8)

(*b*) Identify **one** species acting as an acid, and also identify its conjugate base, in the following system.

$$H_2F_+ + Cl_- \longrightarrow HCl + HF \qquad (6)$$

2006 Question 4 (e)

What is (*i*) the conjugate acid and (*ii*) the conjugate base of H_2O?

2007 Question 7 (a)

(*a*) Define (*i*) *acid*, (*ii*) *conjugate pair*, according to the Brønsted-Lowry theory. (8)
Identify the two conjugate pairs in the following dissociation of nitrous acid (HNO_2):

$$HNO_2 + H_2O \rightleftharpoons NO_{2-} + H_3O_+ \qquad (6)$$

Distinguish between a strong acid and a weak acid.

2009 Question 4 (e)

Define a conjugate pair according to the Brønsted-Lowry theory.

Volumetric Analysis (Acid + Base)

2006 Question 1

An experiment was carried out to determine the percentage water of crystallisation and the degree of water of crystallisation, **x**, in a sample of hydrated sodium carbonate crystals (**$Na_2CO_3.xH_2O$**). An 8.20 g sample of the crystals was weighed accurately on a clock glass and then made up to 500 cm^3 of solution in a volumetric flask. A pipette was used to transfer 25.0 cm^3 portions of this solution to a conical flask. A previously standardised 0.11 M hydrochloric acid (**HCl**) solution was used to titrate each sample. A number of accurate titrations were carried out. The average volume of hydrochloric acid solution required in these titrations was 26.05 cm^3.The titration reaction is described by the equation:

$$Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$$

(*a*) Identify a primary standard reagent which could have been used to standardise the hydrochloric acid solution. (5)
(*b*) Name a suitable indicator for the titration and state the colour change observed in the conical flask at the end point. Explain why not more than 1 – 2 drops of indicator should be used. (12)
(*c*) (*i*) Describe the correct procedure for rinsing the burette before filling it with the solution it is to deliver.
(*ii*) Why is it important to fill the part below the tap of the burette? (12)

(*d*) From the titration figures, calculate the concentration of sodium carbonate (**Na_2CO_3**) in the solution in
(*i*) moles per litre,
(*ii*) grams per litre. (9)

(*e*) Calculate the percentage water of crystallisation present in the crystals and the value of **x**, the degree of hydration of the crystals. (12)

2008 Question 1

To determine the concentration of ethanoic acid, **CH_3COOH**, in a sample of vinegar, the vinegar was first diluted and then titrated against 25.0 cm^3 portions of a previously standardised 0.10 M solution of sodium hydroxide, **NaOH**. One rough and two accurate titrations were carried out.
The three titration figures recorded were 22.9, 22.6 and 22.7 cm^3, respectively.

(a) Why was the vinegar diluted? (5)

(*b*) Describe the correct procedures for measuring exactly 25.0 cm^3 of vinegar and diluting it to exactly 250 cm^3 using deionised water. (15)

(*c*) The equation for the titration reaction is:

$$CH_3COOH + NaOH \longrightarrow CH_3COONa + H_2O$$

Name an indicator suitable for this titration. Justify your choice of indicator.
State the colour change at the end point. (12)

(*d*) Calculate the concentration of the diluted solution of ethanoic acid in
(*i*) moles per litre, (*ii*) grams per litre.

State the concentration of ethanoic acid in the original vinegar sample in grams per litre.
Express this concentration in terms of % (w/v). (15)

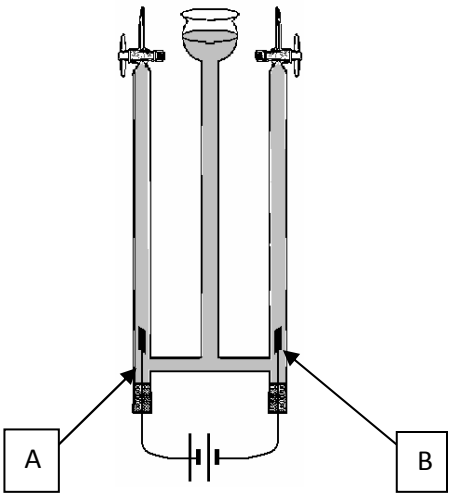
(*e*) Ethanoic acid is a carboxylic acid. Identify the carboxylic acid which occurs in nettles and stinging ants. (3)

Oxidation and Reduction

2004 Question 4 (g)

What is the oxidation number (*i*) of oxygen in $\mathbf{H_2O_2}$ and (*ii*) of bromine in $\mathbf{KBrO_3}$?

2005 Question 11 (a)



(*a*) (*i*) Define *oxidation* in terms of change in oxidation number. (4)
(*ii*) What is observed when chlorine gas is bubbled into an aqueous solution of sodium bromide?
Explain your answer in terms of oxidation and reduction. (9)
(*iii*) A solution of acidified water (dilute sulfuric acid) is electrolysed by passing an electric current through it using inert electrodes.
At which electrode **A** or **B** does oxidation occur?
Which species is oxidised?
Write a balanced half equation for the oxidation reaction. (12)

2006 Question 10 (b)

Define *oxidation* in terms of change in oxidation number. (4)

What is the oxidation number of (*i*) chlorine in **NaClO** and (*ii*) nitrogen in $\mathbf{NO_3^-}$? (6)

State and explain the oxidation number of oxygen in the compound $\mathbf{OF_2}$. (6)

Using oxidation numbers or otherwise, identify the reducing agent in the reaction between acidified potassium manganate(VII) and potassium iodide solutions represented by the balanced equation below. Use your knowledge of the colours of the reactants and products to predict the colour change you would expect to see if you carried out this reaction. (9)

$$2MnO_4^- + 10I^- + 16H^+ \longrightarrow 2Mn2^+ + 5I_2 + 8H_2O$$

2007 Question 10 (c)

The halogens are good oxidising agents.
(*i*) How does the oxidation number of the oxidising agent change during a redox reaction? (4)
(*ii*) Assign oxidation numbers in each of the following equations to show clearly that the halogen is the oxidising agent in each case. (12)

$$Br_2 + 2Fe^{2+} \rightarrow 2Br^- + 2Fe^{3+}$$

$$Cl_2 + SO_3^{2-} + H_2O \rightarrow Cl^- + SO_4^{2-} + H^+$$

Hence or otherwise balance the second equation. (6)
(*iii*) Why does the oxidising ability of the halogens decrease down the group? (3)

2008 Question 8 (b)

Define oxidation in terms of (*i*) electron transfer, (*ii*) change in oxidation number. (7)

(*iii*) For the redox reactions shown below, use oxidation numbers to identify the species oxidised in the first reaction and the oxidising reagent in the second reaction. (6)

$$ClO^- + I^- + H^+ \longrightarrow Cl^- + I_2 + H_2O$$

$$I_2 + S_2O_3^{2-} \longrightarrow I^- + S_4O_6^{2-}$$

(*iv*) Using oxidation numbers or otherwise balance both equations. (12)

Volumetric Analysis (oxidation/reduction)

A solution of sodium thiosulfate was prepared by weighing out a certain mass of crystalline sodium thiosulfate (**$Na_2S_2O_3.5H_2O$**) on a clock glass, dissolving it in deionised water and making the solution up carefully to 500 cm^3 in a volumetric flask. A burette was filled with this solution and it was then titrated against 25.0 cm^3 portions of previously standardised 0.05 M iodine solution in a conical flask. The average titre was 20.0 cm^3.

The equation for the titration reaction is

$$2S_2O_3 + I_2 \rightarrow 2I^- + S_4O_6$$

(*a*) Sodium thiosulfate is not a primary standard. Explain fully the underlined term. (8)
(*b*) Describe how the crystalline thiosulfate was dissolved, and how the solution was transferred to the volumetric flask and made up to exactly 500 cm^3. (15)
(*c*) Pure iodine is almost completely insoluble in water. What must be added to bring iodine into aqueous solution? (3)
(*d*) A few drops of freshly prepared starch solution were added near the end point as the indicator for this titration. What sequence of colours was observed in the conical flask from the start of the titration until the end point was reached? (12)
(*e*) Calculate the molarity of the sodium thiosulfate solution and its concentration in grams of crystalline sodium thiosulfate (**$Na_2S_2O_3.5H_2O$**) per litre. (12)

2009 Question 1

The Fe^{2+} content of iron tablets was determined by titration with a freshly standardised solution of potassium manganate(VII), **$KMnO_4$.**
The equation for the titration reaction is

$$5Fe^{2+} + MnO_4^- + 8H^+ \longrightarrow 5Fe^{3+} + Mn_2+ + 4H_2O$$

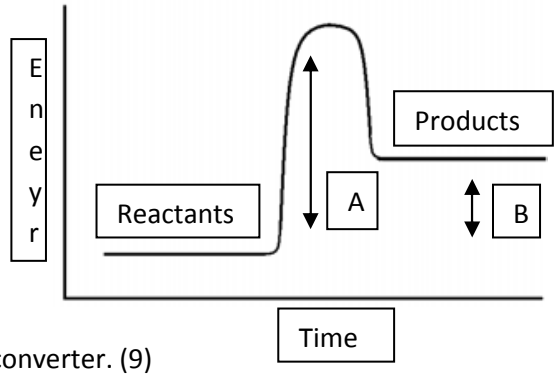
(*a*) Why are iron tablets sometimes medically prescribed? (5)
(*b*) Why must potassium manganate(VII) solutions be standardised? Why was it necessary to standardize the potassium manganate(VII) solution *immediately* before use in the titration? What reagent is used for this purpose? (9)
(*c*) Describe how exactly 250 cm^3 of Fe^{2+} solution was prepared from five iron tablets, each of mass 0.325 g.Why was some dilute sulfuric acid used in making up this solution? (12)
(*d*) Explain why additional dilute sulfuric acid must be added to the titration flask before each titration is carried out. (6)
(*e*) On average, 18.75 cm^3 of 0.01 M potassium manganate(VII) was required to react with 25.0 cm^3 portions of the iron solution prepared from the five tablets. Calculate
(*i*) the molarity of the Fe^{2+} solution,
(*ii*) the total mass of iron in the 250 cm^3 of solution,
(*iii*) the percentage by mass of iron in the tablets. (18)

Rates of Reactions

2004 Question 8

(a) Define the *rate of a chemical reaction*. (5)
Explain why increasing the temperature has a significant effect on the rate of a reaction. (6)

(*b*) The diagram shows a reaction profile diagram for an endothermic
reaction. Name the quantities of energy marked **A** and **B**.
Copy this diagram into your answer book and indicate clearly on your diagram the likely effect of adding a catalyst on the energy profile for the reaction. (12)



(*c*) Catalytic converters are fitted to all modern cars with petrol engines.
Name **two** elements used as catalysts in a catalytic converter.
Name **one** substance which poisons the catalysts in a catalytic converter. (9)

(*d*) The oxidation of potassium sodium tartrate by hydrogen peroxide catalysed by cobalt(II) ions provides evidence for the intermediate formation theory of catalysis. State the observations you would make when carrying out this experiment.
Explain how these observations provide evidence for the intermediate formation theory. (18)

2005 Question 3

Hydrogen peroxide decomposes rapidly in the presence of a manganese(IV) oxide (**MnO_2**) catalyst.

(*a*) Write a balanced equation for the decomposition of hydrogen peroxide. (5)
(*b*) Draw a labelled diagram of an apparatus a student could assemble to measure the rate of decomposition of hydrogen peroxide in the presence of a manganese(IV) oxide (**MnO_2**) catalyst. Indicate clearly how the reaction could be started at a time known exactly, and how the gas Produced is collected and its volume measured. (12)
(*c*) A student has a choice of using the same mass of finely powdered manganese(IV) oxide or coarsely powdered (granulated) manganese(IV) oxide. Which of these would you expect to have a greater average rate of reaction over the first minute of the reaction? Give a reason for your answer. (6)
A set of results obtained in an experiment to measure the rate of decomposition of hydrogen peroxide, in a solution of known volume and concentration, is given in the table.

Time/minutes	0	1	2	3	4	5	6	7	8
Volume of **O_2**/cm^3	0.0	13.5	23.4	30.5	35.4	38.3	39.6	40.0	40.0

(*d*) Plot a graph to illustrate the volume of oxygen produced *versus* time. (12)
(*e*) Use the graph to determine
(*i*) the volume of oxygen produced during the first 2.5 minutes and
(*ii*) the instantaneous rate of the reaction at 2.5 minutes. (9)
(*f*) What changes would you expect in the graph if the experiment were repeated using a solution of the

same volume but exactly half the concentration of the original hydrogen peroxide solution? (6)

2006 Question 7

(*a*) Define the *activation energy* of a chemical reaction. (5)
(*b*) Give **two** reasons why the rate of a chemical reaction increases as the temperature rises.
Which of these is the more significant? Why? (12)
(*c*) Describe how you could investigate the effect of temperature on the rate of the reaction between a 0.1 M sodium thiosulfate solution and a 2 M hydrochloric acid solution. (12)
The reaction is described by the following balanced equation.

$$\mathbf{Na_2S_2O_3 + 2HCl \longrightarrow 2NaCl + SO_2 + S + H_2O}$$

(*d*) When silver nitrate and sodium chloride solutions are mixed a precipitate appears immediately. Explain the speed of this reaction compared to the slower reaction when solutions of sodium thiosulfate and hydrochloric acid are mixed. (6)
(*e*) What type of catalysis occurs in the catalytic converter of a modern car?
Give the names *or* formulas of **two** substances entering a car's catalytic converter and the names *or* formulas of the substances to which they are converted in the interior of the catalytic converter. (15)

2007 Question 4 (d)

What is meant by *heterogeneous* catalysis?

2007 Question 9

(*a*) Define the *rate of a chemical reaction*.
Why does the rate of chemical reactions generally decrease with time? (8)
(*b*) The rate of reaction between an excess of marble chips (**$CaCO_3$**) (diameter 11 – 15 mm) and 50 cm^3 of 2.0 M hydrochloric acid was monitored by measuring the mass of carbon dioxide produced.
The table shows the total mass of carbon dioxide gas produced at stated intervals over 9 minutes.

Time/minutes	0.0	1.0	2.0	3.0	4.0	5.5	7.0	8.0	9.0
Mass of **CO_2**/g	0.00	0.66	1.20	1.60	1.90	2.10	2.18	2.20	2.20

Plot a graph of the mass of carbon dioxide produced *versus* time. (12)
Use the graph to determine
(*i*) the instantaneous rate of reaction in grams per minute at 4.0 minutes,
(*ii*) the instantaneous rate of reaction at this time in moles per minute. (9)
(*c*) Describe and explain the effect on the rate of reaction of repeating the experiment using 50 cm^3 of 1.0
M hydrochloric acid and the same mass of the same size marble chips. (6)
(*d*) Particle size has a critical effect on the rate of a chemical reaction.
(*i*) Mark clearly on your graph the approximate curve you would expect to plot if the experiment were repeated using 50 cm^3 of 2.0 M HCl and using the same mass of marble chips but this time with a diameter range of 1 – 5 mm. (6)
(*ii*) Dust explosions present a risk in industry. Give **three** conditions necessary for a dust explosion to occur. (9)

2008 Question 3

(*a*) Hydrogen peroxide solution is an oxidising reagent. Draw *or* describe the warning symbol put a container of hydrogen peroxide solution to indicate this hazard. (5)
(*b*) Write a balanced equation for the decomposition of hydrogen peroxide. (6)
(*c*) Solid manganese(IV) oxide catalyst was added to a hydrogen peroxide solution at a time known exactly and the rate of production of gas was monitored as the hydrogen peroxide decomposed. Draw a labelled diagram of an apparatus that could be used to carry out this experiment. (12)
(*d*) The table shows the volumes of gas (at room temperature and pressure) produced at intervals over 12 minutes.

Time / minutes	0.0	1.0	2.0	3.0	5.0	7.0	9.0	11.0	12.0
Volume / cm^3	0.0	20.0	36.0	50.5	65.5	73.0	76.5	78.0	78.0

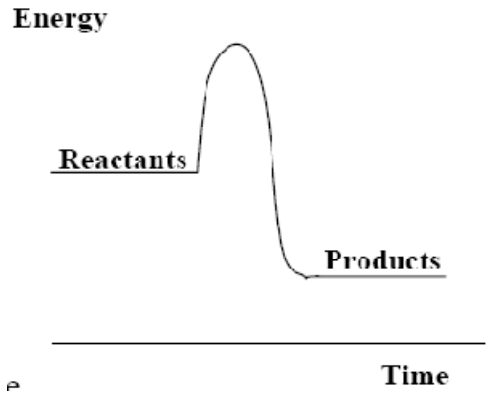
Plot a graph of the volume of gas produced *versus* time.
Explain why the graph is steepest at the beginning. (15)

(*e*) Use your graph to
(*i*) determine the instantaneous rate of gas production at 5 minutes,
(*ii*) calculate the total mass of gas produced in this experiment. (12)

2008 Question 4 (f) + (h)

Name **two** metals which act as catalysts in the catalytic converters of modern cars.

Copy the diagram of an exothermic reaction profile into your answer book and mark clearly (*i*) the activation energy, (*ii*) ΔH for the reaction.



2009 Question 9

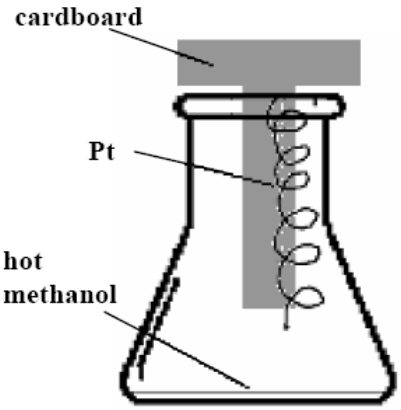
(*a*) Explain (*i*) activation energy, (*ii*) effective collision. (8)
The effect of temperature on the rate of a chemical reaction was investigated using dilute solutions of hydrochloric acid and sodium thiosulfate. Suitable volumes and concentrations of the solutions were used. The reaction is represented by the following balanced equation.

$$2HCl + Na_2S_2O_3 \longrightarrow 2NaCl + H_2O + S + SO_2$$

Describe how the time for the reaction between the solutions of hydrochloric acid and sodium thiosulfate was obtained at room temperature. (6)
In a reaction mixture what effect, if any, does an increase in temperature of 10 K have on each of the

following:
(*i*) the number of collisions, (*ii*) the effectiveness of the collisions, (*iii*) the activation energy. (9)

(*b*) The catalytic oxidation of methanol using platinum wire is illustrated in the diagram.
State **one** observation made during the experiment.
Name any **two** products of the oxidation reaction.
What type of catalysis is involved in this reaction? (12)
Explain **one** way in which the presence of the platinum catalyst speeds up the oxidation of the hot methanol.
Explain how a catalyst poison interferes with this type of catalysis. (9)
Give another example of a reaction which involves the same type of catalysis, indicating clearly the reactant(s) and the catalyst. (6)



Chemical Equilibrium

2004 Question 9

(*a*) What is meant by *chemical equilibrium*? Why is it described as a *dynamic* state? (8)
Consider the following reversible chemical reaction:

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} \quad \Delta H = -92.4 \text{ kJ}$$

(*b*) Use Le Chatelier's principle to predict the levels (high or low) of temperature and pressure needed to maximise the yield of ammonia when equilibrium is established. Give a reason (*i*) for the temperature level you have predicted, (*ii*) for the level of pressure you have predicted. (12)

(*c*) Are the temperature levels predicted using Le Chatelier's principle actually used to maximise ammonia yield in industry? Explain your answer. (6)

(*d*) What is the effect of a catalyst on a reversible reaction? (6)

(*e*) In an experiment 6.0 moles of nitrogen and 18.0 moles of hydrogen were mixed and allowed to come to equilibrium in a sealed 5.0 litre vessel at a certain temperature. It was found that there were 6.0 moles of ammonia in the equilibrium mixture.
Write the equilibrium constant expression for the reaction and calculate the value of the equilibrium constant (K_c) at this temperature. (18)

2005 Question 9

(a) State *Le Chatelier's principle*. (5)

(*b*) A student is provided with glassware and other laboratory apparatus as well as the following chemicals: potassium dichromate(VI) (**$K_2Cr_2O_7.2H_2O$**), hydrochloric acid (**$HCl_{(aq)}$**), sodium hydroxide (**NaOH**), cobalt(II) chloride crystals (**$CoCl_2.6H_2O$**) and deionised water (**H_2O**).
(*i*) Describe clearly how the student could use a selection of the chemicals listed above to establish a chemical equilibrium. Write a balanced equation for the equilibrium. (12)
(*ii*) Describe how the student could then demonstrate the effect of concentration on that chemical equilibrium. State the observations made during the demonstration. (9)

(*c*) The value of K_c for the following equilibrium reaction is 4.0 at a temperature of 373 K.

$$CH_3COOH + C_2H_5OH \rightleftharpoons CH_3COOC_2H_5 + H_2O$$

(*i*) Write the equilibrium constant (K_c) expression for this reaction. (6)
(*ii*) What mass of ethyl ethanoate (**$CH_3COOC_2H_5$**) would be present in the equilibrium mixture if 15 g of ethanoic acid and 11.5 g of ethanol were mixed and equilibrium was established at this temperature? (18)

2006 Question 11 (b)

State *Le Châtelier's principle*. (7)

The following equilibrium is set up in solution by dissolving cobalt(II) chloride crystals in water to form the pink species **$Co(H_2O)_6$** and then adding concentrated hydrochloric acid until the solution becomes blue.

$$\underset{\text{Pink}}{Co(H_2O)_6} + 4Cl^- \rightleftharpoons \underset{\text{blue}}{CoCl_4} + 6H_2O$$

(*i*) When the solution becomes blue, has reaction ceased? Explain. (6)
(*ii*) The forward reaction is endothermic. State and explain the colour change observed on cooling the reaction mixture. (6)
(*iii*) Other than heating, mention **one** way of reversing the change caused by cooling the reaction mixture. (6)

2007 Question 10 (a)

(i) Write the equilibrium constant (***K*c**) expression for the reaction (7)

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

(*ii*) Three moles of nitrogen gas and nine moles of hydrogen gas were mixed in a 1 litre vessel at a temperature *T*. There were two moles of ammonia in the vessel at equilibrium. Calculate the value of ***K*c** for this reaction at this temperature. (12)
(*iii*) Henri Le Chatelier, pictured on the right, studied equilibrium reactions in industry in the late 19th century. According to Le Chatelier's principle, what effect would an increase in pressure have on the yield of ammonia at equilibrium? Explain. (6)

2008 Question 7

A chemical equilibrium is established when eleven moles of hydrogen and eleven moles of iodine are mixed at a temperature of 764 K. Initially the colour of the mixture is deep purple due to the high concentration of iodine vapour. The purple colour fades and when equilibrium is established the colour ofthe mixture is pale pink and there are seventeen moles of hydrogen iodide present.
The equilibrium is represented by the equation

$$\underset{\text{colourless}}{H_{2(g)}} + \underset{\text{purple}}{I_{2(g)}} \rightleftharpoons \underset{\text{colourless}}{2HI_{(g)}} \qquad \Delta H = 51.8\ \text{kJ}$$

(*a*) What is meant by *chemical equilibrium*?
When the colour of the mixture has become pale pink, has reaction ceased? Explain. (11)
(*b*) Write an expression for the equilibrium constant (***K*c**) for the reaction. (6)
Calculate the value of the equilibrium constant (***K*c**) at 764 K. (12)
(*c*) State *Le Châtelier's principle*. (6)

Use Le Châtelier's principle to predict and explain the effect of a decrease in temperature on (*i*) the yield of hydrogen iodide, (*ii*) the intensity of colour of the equilibrium mixture. (9)

What change, if any, will an increase in the pressure on the equilibrium mixture have on the yield of hydrogen iodide? Explain. (6)

2009 Question 11(a)

(*a*) Ammonia is formed in the Haber process according to the following balanced equation.

$$3H_{2(g)} + N_{2(g)} \rightleftharpoons 2NH_{3(g)}$$

The table shows the percentages of ammonia present at equilibrium under different conditions of temperature *T* and pressure *P* when hydrogen and nitrogen gases were mixed in a 3:1 molar ratio.

P/atm \ *T*/K	573	673	773
10	15	4	1
100	51	25	10
200	63	36	18
1000	92	80	58

(*i*) Find from the table the conditions of temperature and pressure at which the highest yield of ammonia is obtained. (4)

(*ii*) Deduce from the data whether this reaction is exothermic or endothermic. Explain your reasoning. (6)

(*iii*) Identify **one** industrial problem associated with the use of high pressures. (3)

(*iv*) Write an equilibrium constant (K_c) expression for this reaction. (6)

(*v*) State the effect on the value of K_c of using a catalyst. Justify your answer. (6)

pH and Indicators

2004 Question 11 (b)

Define pH. (7)

(i) What are the limitations of the pH scale? (6)

(*ii*) Calculate the approximate pH of a vinegar solution that contains 4.5 g of ethanoic acid per 100 cm^3. The value of K_a for ethanoic acid is 1.8×10^{-5}. (12)

2005 Question 8 (c)

(*c*) Calculate the pH of a 0.002 M solution of methanoic acid (**HCOOH**).
The value of K_a for methanoic acid is 1.8×10^{-4}. (12)

2006 Question 4 (h)

The concentration of an aqueous solution of sodium hydroxide (**NaOH**) is 0.2 g per litre.
Calculate its pH.

2006 Question 8 (b)

(*i*) Explain how an acid-base indicator, which is itself a weak acid, and may be represented by **HX**, functions. (9)
(*ii*) Draw a clearly labelled diagram of the titration curve you would expect to obtain when 50 cm^3 of a 0.1 M sodium hydroxide (**NaOH**) solution is added slowly to 25 cm^3 of a 0.1 M ethanoic acid (**CH_3COOH**) solution. (9)
(*iii*) Explain with reference to your diagram why phenolphthalein is a suitable indicator for a titration of sodium hydroxide with ethanoic acid. (6)

2007 Question 7 (b)

Calculate the pH of 0.1 M nitrous acid (**HNO_2**); the value of the acid dissociation constant (***K_a***)for nitrous acid is 5.0×10^{-4}.

What is the pH of a nitric acid (**HNO_3**) solution of the same concentration? (15)

2008 Question 8 (a)

(a) (*i*) Write an expression for the self-ionisation of water. (5)
(*ii*) Define ***K_w***, the ionic product of water.
The value of ***K_w*** at 25 ºC is 1.0×10^{-14}. Show that the pH of pure water is 7.0 at 25 ºC. (12)

(*iii*) Calculate the pH of a 0.5 M solution of a strong monobasic (monoprotic) acid.
Calculate the pH of a 0.5 M solution of a weak monobasic acid with a ***K_a*** value of 1.8×10^{-5}. (12)

2009 Question 4(f)

Calculate the pH of a 0.025 M solution of nitric acid.

Environmental Chemistry (Water)

2004 Question 1

In an experiment to determine the total hardness of a water sample containing both calcium and magnesium ions, a solution of the reagent **edta** (ethylenediaminetetraacetic acid) in the form of its disodium salt (represented by $\mathbf{Na_2H_2Y}$) was titrated against a sample of the water using a suitable indicator. The reaction between the ions (represented by $\mathbf{M^{2+}}$) in the hard water and the **edta** reagent may be represented as

$$M^{2+} + H_2Y^{2-} \longrightarrow MY^{2-} + 2H^+$$

(*a*) Name a suitable indicator for this titration.
What colour change is observed at the end point of the titration using this indicator? (8)

(*b*) Describe the correct procedure for rinsing the burette and filling it with **edta** reagent. (15)

(*c*) The addition of a small quantity of another solution to the water in the conical flask is essential before commencing the titration. What solution must be added and what is its purpose? (6)

(*d*) In the experiment it was found that 100 cm^3 portions of the water required an average titre of 8.10 cm^3 of 0.010 M **edta** solution. Calculate the total hardness in
(*i*) moles per litre,
(*ii*) grams per litre expressed in terms of $\mathbf{CaCO_3}$ and
(*iii*) p.p.m. expressed in terms of $\mathbf{CaCO_3}$. (15)

(*e*) A whitish deposit is often found on the insides of kettles in hard water districts. If some of this deposit is scraped into a test tube and dilute hydrochloric acid is added a reaction is observed. Write a balanced equation for this reaction. (6)

2004 Question4 (f)

How are heavy metals, e.g. mercury, removed from industrial waste before it is discharged into rivers, lakes or the sea?

2005 Question 1

In an experiment to measure the concentration of dissolved oxygen in a river water sample, a bottle of water was filled from the river and it was analysed immediately. The experiment was carried out as follows:
A few cm^3 each of concentrated manganese(II) sulfate ($\mathbf{MnSO_4}$) solution and alkaline potassium iodide (**KOH/KI**) solution were added to the water in the bottle. The stopper was carefully replaced on the bottle and the bottle was shaken to ensure mixing of the reagents with the water. A brownish precipitate was produced. The stopper was removed from the bottle and a few cm^3 of concentrated sulfuric acid ($\mathbf{H_2SO_4}$)were added carefully down the inside of the neck of the bottle using a dropper. The precipitate dissolved and a golden-brown solution was produced. The concentration of iodine ($\mathbf{I_2}$) in this solution was found by titrating it in 50 cm^3 portions against a standard (0.01 M) sodium thiosulfate ($\mathbf{Na_2S_2O_3}$) solution.

(*a*) Why was it necessary to analyse the sample of river water *immediately*? (5)
(*b*) In making the additions to the sample, why should the solutions used be *concentrated*? (6)
(*c*) Describe how the additions of the concentrated solution of manganese(II) sulfate (**$MnSO_4$**) and alkaline potassium iodide (**KOH/KI**) to the bottle of river water should be carried out. What essential precaution should be taken when replacing the stopper of the bottle after these additions are made? (9)
(*d*) Describe clearly the procedure for using a pipette to measure exactly 50 cm^3 portions of the iodine (**I_2**) solution into the titration flask. (9)
(*e*) What indicator is used in this titration? State when the indicator should be added to the titration flask and describe the colour change observed at the end point. (9)
(*f*) The titration reaction is described by the following equation.

$$2S_2O_3 + I_2 \rightarrow 2I^- + S_4O_6$$

Calculate the concentration of the iodine solution in moles per litre given that 6.0 cm^3 of the 0.01 M sodium thiosulfate (**$Na_2S_2O_3$**) solution were required in the titration for complete reaction with 50 cm^3 portions of the iodine solution. (6)

(*g*) For every 1 mole of oxygen gas (**O_2**) in the water sample 2 moles of iodine (**I_2**) are liberated in this experiment. Hence calculate the concentration of dissolved oxygen in the water sample in p.p.m. (6)

2005 Question 8 (d) + (e)

(*d*) What is meant by the *biochemical oxygen demand* (*BOD)* of a water sample? (6)

(*e*) Describe clearly the processes involved in the primary and secondary stages of urban sewage treatment. What substances are removed by tertiary treatment of sewage? (18)

2006 Question 3
A number of tests were carried out on a sample of swimming pool water to test its quality.
(*a*) A colorimetric experiment was used to estimate the concentration of free chlorine in the sample. What is the general principle of all colorimetric experiments? (8)
(*b*) Identify a suitable reagent to test for free chlorine in swimming pool water and state the colour which develops when this reagent reacts with free chlorine. (6)
(*c*) Describe briefly how you would estimate the concentration of free chlorine in a sample using either a comparator or a colorimeter. (12)
(*d*) Give the name or formula of a *free chlorine* species in the swimming pool water.
Give a reason why the concentration of free chlorine in treated drinking water is usually between 0.2 - 0.5 p.p.m. whereas in swimming pool water it should be between 1 - 5 p.p.m. (9)
(*e*) When 1200 cm^3 of swimming pool water was filtered, the mass of the filter paper, upon drying, had increased by 0.78 g. When 250 cm^3 of the filtered water was evaporated to dryness the mass of the residue obtained was 0.32 g. Calculate the concentration in p.p.m.
(*i*) of suspended solids,
(*ii*) of dissolved solids. (15)

2006 Question 8 (a)

(*a*) (*i*) What is *hard water*? (5)
(*ii*) A supply of hard water is treated for domestic use by ion-exchange. You may assume that all the

hardness is due to **$Ca(HCO_3)_2$**. Explain in words or using a balanced equation how a cation exchange resin, represented by **RNa**, softens this water supply. (6)

(*iii*) In the treatment of water for drinking, what is meant by the term *flocculation*? Name a flocculating agent. (9)

(*iv*) What substance is added to water to adjust the pH if the water is too acidic? Why is it undesirable to have the pH of drinking water below 6? (6)

2007 Question 7 (c)+(d)

(*c*) *Eutrophication* in water may result from the addition of large quantities of nitrate fertilizers to it. Describe the processes occurring in the water leading to eutrophication. (9)

(*d*) Explain how heavy metal ions are removed from large quantities of water. (6)

2008 Question 4 (e)

Write the formula of (*i*) a substance which causes temporary hardness in water, (*ii*) a substance which causes permanent hardness in water.

2008 Question 8 (b)

(*i*) Explain clearly how suspended solids are removed in the treatment of water for drinking. (9)

(*ii*) Identify **two** chemicals added at the final stages of the treatment of water for drinking. State the purpose of adding each chemical you have identified. (12)

2008 Question 10 (a) (i)+ (ii)

A student is given a bucket of seawater.

(*i*) Describe how the student could determine by filtration the total suspended solids (expressed as ppm) in the water. (9)

(*ii*) How could the student determine the total dissolved solids (expressed as ppm) in a sample of the filtered seawater? (9)

2009 Question 4 (g)

When water that contains temporary hardness is boiled in a kettle, scale is formed on the heating element. Identify the chemical that is the main component of this scale.

2009 Question 7

(*a*) According to the EPA (Environmental Protection Agency) publication 'The Provision and Quality of Drinking Water in Ireland (2006-2007)': *Drinking water must be clean and wholesome. That means it must meet the relevant water quality standards and must not contain any other substance or microorganism in concentration or numbers that constitute a potential danger to human health.*

(*i*) Describe how suspended solids are removed in water treatment.

(*ii*) What treatment is carried out to ensure low levels of micro-organisms in drinking water?

(*iii*) What problems would arise if the pH of a public water supply were outside the range 6 – 8?
(*iv*) EU standards specify that the concentration of lead (in the form of Pb^{2+}) in drinking water must be below 10 µg/l (micrograms per litre). Why must the Pb^{2+} concentration be kept so low? How are heavy metal ions like Pb^{2+} removed from large quantities of water? (23)
*(*b) Quoting from the EPA website: *The main threat to surface water quality is eutrophication, which is* The over-abundant growth of plants and algae arising from excess nutrients in the water.

(*i*) What are the nutrients referred to above? At what stage of sewage treatment are their levels lowered so that eutrophication does not occur downstream from sewage works? (9)
(*ii*) A sample of brewery effluent was diluted from 50 cm^3 to 5.0 litres with well-aerated pure water. The dissolved oxygen concentration of half the sample was measured immediately; the other half was stored under suitable conditions and its dissolved oxygen concentration was measured later. Concentrations of dissolved oxygen of 9.8 ppm and 4.7 ppm, respectively, were recorded. What are the suitable conditions for, and the duration of, storage of the second sample? Calculate the BOD of the brewery effluent. (18)

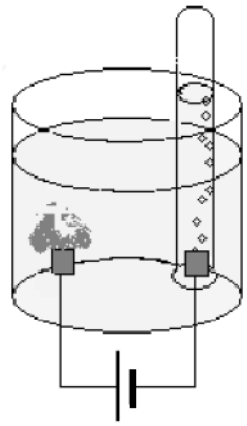
Electrochemistry

2004 Question 4 (i)

State and explain the colour observed at the negative electrode in the electrolysis of aqueous potassium iodide, containing a little phenolphthalein indicator, using inert electrodes.

2009 Question 10(b)

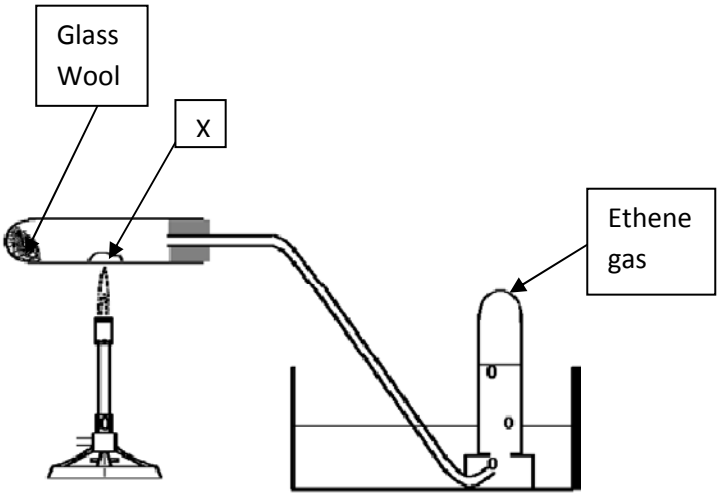
Define oxidation in terms of electron transfer. (4)
The electrolysis, using inert electrodes, of aqueous potassium iodide, **KI**, to which a few drops of phenolphthalein indicator have been added, is shown in the diagram.
(*i*) Name a suitable material for the electrodes. (3)
(*ii*) Write balanced half equations for the reactions that take place at the electrodes. (12)
(*iii*) Explain the colour change observed at the positive electrode (anode). (6)



Fuels and Heats of Reaction

2004 Question 2

The diagram shows the experimental set-up used by a group of students to prepare a sample of ethene from ethanol and to collect the ethene produced.



(*a*) What is the function of the glass wool? (5)
Identify the solid **X** and describe its appearance. (6)

(*b*) State and explain **two** safety precautions which should be observed when carrying out the student experiment. (12)

(*c*) Write a balanced equation for the reaction involved in this preparation. (6)

(*d*) If the ethene produced is bubbled through an acidified solution of potassium manganate(VII), the solution is decolorised showing that ethene is *unsaturated*. What is meant by the term *unsaturated*? Describe how you would carry out another test to confirm that ethene is unsaturated. (12)

(*e*) Describe the flame that would be observed when a combustion test is carried out on a sample of ethane gas. Write a balanced equation for the combustion of ethene in excess oxygen. (9)

2004 Question 6

(a) Define (i) heat of formation of a substance, (ii) octane number of a fuel. (11)

(*b*) The combustion of methane is described by the following balanced equation.

$$CH_{4(g)} + 2O_{2(g)}\ CO_{2(g)} + 2H_2O_{(l)} \qquad \Delta H = -890.4\ \text{kJ mol}^{-1}$$

The standard heats of formation of carbon dioxide and water are −394 and −286 kJ mol^{-1} respectively. Calculate the heat of formation of methane. (12)

(c) Methane is an excellent fuel. Give two properties of methane which account for its usefulness as a fuel.
Natural gas is a rich source of methane. Why are mercaptans often added to natural gas? (9)

(*d*) Methane is often found in gas fields which occur in association with crude oil deposits. Crude oil is fractionated in order to obtain more useful products. Outline clearly how the fractionation process is carried out. (12)

(*e*) Identify **two** structural features of a hydrocarbon fuel which affect its octane number. (6)

2005 Question 4 (g) + (i)

Name and draw the structure of an aromatic compound of molecular formula C_8H_{10}.

Draw the structural formula of an organic compound of molecular formula **C_3H_6**. Label clearly any tetrahedrally bonded carbon atom in the molecule.

2005 Question 6

(*a*) The octane number of a fuel is described as *a measure of the tendency of the fuel to cause knocking*, or as *a measure of the tendency of the fuel to resist auto-ignition*. This number is found by comparing the combustion of the fuel with the combustion of a mixture of two reference hydrocarbons using the same standard engine.
(*i*) Name **both** of the reference hydrocarbons present in the mixture used when measuring octane number by this comparison method. (8)
(*ii*) State **two** structural features of a hydrocarbon molecule which contribute to it having a high octane number. (6)
(*iii*) Lead compounds were used in the past to increase the octane number of fuels. Why are lead compounds unsuitable as additives for petrol used in modern cars? (3)
(*iv*) Identify **one** additive *or* type of additive, other than a compound of lead, used to increase the octane number of fuels. (3)

(*b*) There are **three** structural isomers of the hydrocarbon of formula **C_5H_{12}**. In the case of **each** of these isomers, draw the structure of the molecule and give its systematic IUPAC name. (18)

(*c*) The combustion of liquid benzene is described by the following equation:

$$2C_6H_{6(l)} + 15O_{2(g)} \rightarrow 12CO_{2(g)} + 6H_2O_{(l)}$$

Given that the heats of formation of carbon dioxide gas, liquid water and liquid benzene are –394, –286 and 49 kJ mol^{-1} respectively, calculate the heat of combustion of liquid benzene. (12)

2006 Question 6

(*a*) The table shows the octane numbers of four hydrocarbons.

Name	Formula	Octane Number
hexane	C_6H_{14}	25
cyclohexane	C_6H_{12}	83
benzene	C_6H_6	100
2,2,4-trimethylpentane	C_8H_{18}	100

(*i*) What is meant by the octane number of a fuel? (8)
(*ii*) Hexane has the lowest octane number of the four compounds listed. What structural feature of the molecule contributes to this? (3)
(*iii*) In the case of each of the other three compounds, identify the structural feature of its molecules which contributes to it having a high octane number. (9)
(*iv*) Name the process carried out in an oil refinery that converts hexane to compounds such as cyclohexane and benzene. Why is the use of benzene in petrol strictly controlled? (6)

(*b*) (*i*) Give **two** reasons why oxygenates such as MTBE are added to petrol.
(*ii*) Give **two** reasons why the addition of lead to petrol has been discontinued. (12)

(*c*) The combustion of cyclohexane may be described by the following balanced equation:

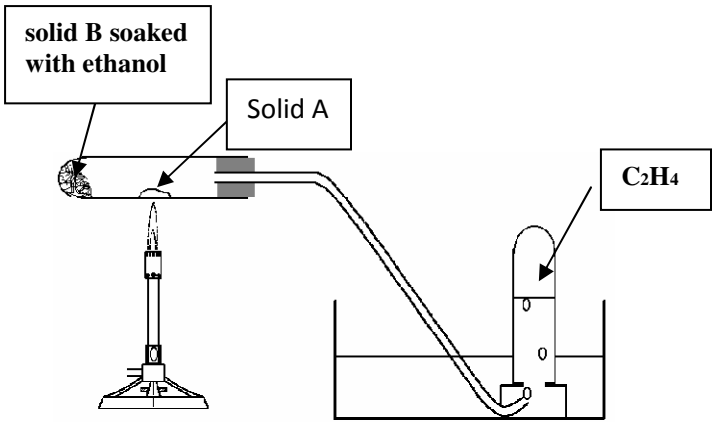
$$C_6H_{12(l)} + 9O_{2(g)} \longrightarrow 6CO_{2(g)} + 6H_2O_{(l)}$$

Given that the heats of formation of cyclohexane, carbon dioxide and water are –156, –394 and –286 kJ mol^{-1}, respectively, calculate the heat of combustion of cyclohexane. (12)

2006 Question 9

The alkenes are a homologous series. Ethene (**C_2H_4**) is the first member of the series.

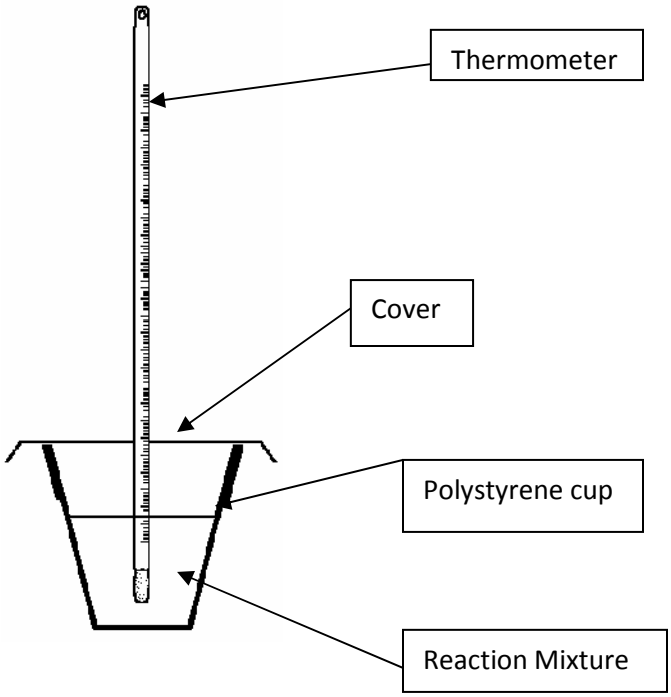
(*a*) What is meant by a *homologous series*? (5)
(*b*) Ethene may be made in a school laboratory using the arrangement of apparatus drawn on the right.
(*i*) Give the name and formula of the solid **A** which is heated using the Bunsen burner. (6)
(*ii*) Identify the solid **B** which is used to keep the ethanol at the end of the test tube. (3)
(*iii*) What precaution should be observed when heating is stopped? Why is this necessary? (6)
(*iv*) Give **one** major use of ethene gas. (3)



(*d*) Draw the structures and give the systematic (IUPAC) names for **two** alkene isomers of molecular formula **C_4H_8**. (12)

2007 Question 3

In an experiment to measure the heat of reaction for the reaction between sodium hydroxide with hydrochloric acid, a student added 50 cm^3 of 1.0 M **HCl** solution to the same volume of 1.0 M **NaOH** solution in a polystyrene foam cup.



(*a*) To achieve an appreciable temperature rise during the reaction, quite concentrated solutions of acid and base, carrying the label illustrated, were used.
What word describes the chemical hazard illustrated in this label?
State **one** precaution the student should take when using these solutions. (8)

(*b*) The student had a choice of using either a graduated cylinder or a burette to measure out the solutions used in this experiment.
Which piece of apparatus should have been used to achieve the more accurate result? (3)

(*c*) If the hydrochloric acid and sodium hydroxide solutions had been stored at slightly different temperatures, explain how the initial temperature of the reaction mixture could have been obtained. (6)

(*d*) List **three** precautions which should have been taken in order to obtain an accurate value for the highest temperature reached by the reaction mixture. (9)

(*e*) What was the advantage of mixing the solutions in a polystyrene foam cup rather than in a glass beaker or in a metal calorimeter? (3)

(*f*) Calculate the number of moles of acid neutralised in this experiment.
Taking the total heat capacity of the reaction mixture used in this experiment as 420 J K^{-1}, calculate The heat released in the experiment if a temperature rise of 6.7 ºC was recorded.

Hence calculate the heat of reaction for

$NaOH + HCl \rightarrow NaCl + H_2O$ (18)

(*g*) Name the piece of apparatus used in industry to accurately measure the heats of combustion of foods and fuels. (3)

2007 Question4 (b) + (i)

What is the principal use made of oxygenates such as methyl *tert*-butyl ether, MTBE, in the petrochemicals industry?

Explain in terms of bonding why it is more correct to represent the benzene molecule as:

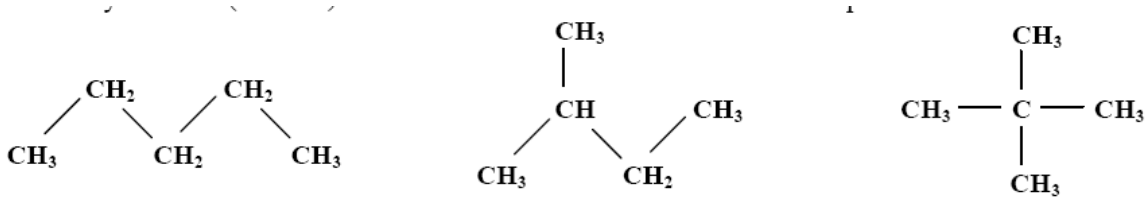
instead of

or

2007 Question 6

Useful hydrocarbons are obtained by the fractional distillation of crude oil, which itself has little or no direct use. Hydrocarbons are excellent fuels.

(*a*) In which fraction of crude oil do pentane and its isomers occur? (5)
Give the systematic (IUPAC) name of each of the structural isomers of pentane shown below. (9)



Which of these isomers would you predict to have the lowest octane number?
Justify your choice in terms of the structural features of the molecules. (9)
Write a balanced equation for the combustion of pentane (**C_5H_{12}**) in excess oxygen. (6)
(*b*) Naphtha and gas oil are two of the hydrocarbon fractions obtained from the fractional distillation of crude oil. How do the molecules of the naphtha fraction differ from the molecules of the gas oil fraction? (3)
Explain with the aid of a labelled diagram how naphtha (b.p. approximately 100 ºC) is separated from gas oil (b.p. approximately 300 ºC) in the fractional distillation of crude oil. (9)
Bitumen is a residue fraction obtained from crude oil. Give **one** use for bitumen. (3)
(*c*) What is catalytic cracking? What is its economic importance in oil refining? (6)

2008 Question 6

(*a*) The hydrocarbon molecules in petrol typically contain carbon chains with between five and ten carbon atoms. The most widely used petrol in Ireland has an octane number of 95.
(*i*) What is meant by the *octane number* of a fuel? (5)
(*ii*) The two hydrocarbons used as references when establishing the octane number of a fuel are heptane and 2,2,4-trimethylpentane. Draw the structure of each of these molecules. (6)
(*iii*) Crude oil is separated into a number of fractions in oil refining. Name the **two** fractions which contain molecules with the carbon chain lengths needed for petrol. (6)
(*iv*) Dehydrocyclisation is one of the processes used to increase the octane numbers of hydrocarbons. What **two** changes to the hydrocarbon molecules occur during this process? (6)
(*v*) Ethanol is an example of an oxygenate. Give another example of an oxygenate. Give **two** reasons why oxygenates are added to petrol. (9)
(*b*) Write a balanced chemical equation for the combustion of ethanol, **C_2H_5OH**.
Given that the heats of formation of ethanol, carbon dioxide and water are –278, –394 and –286 kJ mol^{-1}, respectively, calculate the heat of combustion of ethanol. (18)

2008 Question 9 (a), (b) + (c)

The alkenes are a homologous series of *unsaturated* hydrocarbons. Ethene (**C_2H_4**) is the first member of the series. Alkenes undergo addition reactions and polymerisation reactions.

(*a*) Draw a labelled diagram of an apparatus used to prepare ethene gas in the school laboratory. (8)
(*b*) Draw the structure of any one of the isomers of the third member of the alkene series. Indicate clearly which carbon atoms have planar bonding and which are bonded tetrahedrally. (12)
(*c*) Explain the term *unsaturated*. (6)

2009 Question 2

Ethene can be prepared in the school laboratory using the arrangement of apparatus shown in Diagram 1.
Ethyne can be prepared in the school laboratory using the arrangement of apparatus shown in Diagram 2.

(a) Give the name or chemical formula of the solid **X** used in the preparation of ethane.
What is the colour of this solid? (5)

(*b*) Write a balanced equation for the reaction involved in the preparation of ethene. What term describes this type of reaction? (6)

(*c*) State **three** precautions that should be observed when carrying out the preparation of ethene by this method. (9)

(*d*) Give the name or formula of the solid **Y** used in the preparation of ethyne in the school laboratory. Describe the appearance of this solid. (6)

(*e*) Both ethene and ethyne are described as *unsaturated*.
What does this mean? Describe a test you could carry out on a sample of either gas to show that it is unsaturated.
What would you observe during the test? (9)

(*f*) Both ethene and ethyne can be burned in air.
What is the most noticeable difference seen when these combustions are carried out in a school laboratory?
Write a balanced equation for the complete combustion of either gas. (9)

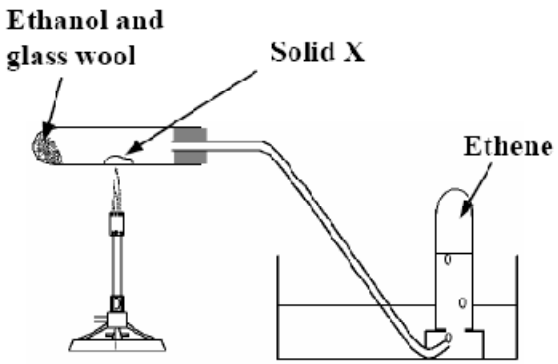


Diagram 1

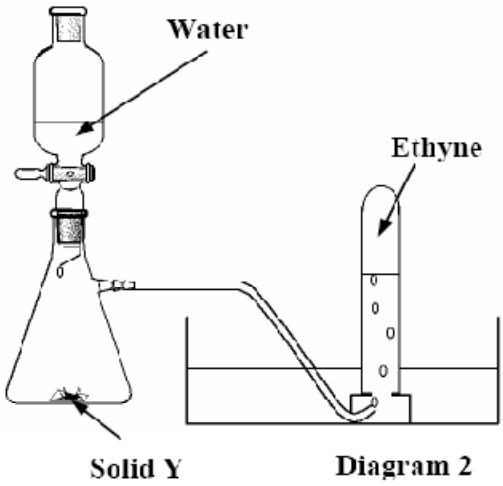


Diagram 2

(*g*) Give (*i*) a major use of ethene,
(*ii*) a major use of ethyne. (6)

2009 Question 6

(*a*) Define (*i*) hydrocarbons, (*ii*) structural isomers. (8)
(*b*) Give a use for the kerosene fraction obtained when crude oil is fractionated.
Explain why some of the kerosene produced in oil refining is subjected to catalytic cracking. (9)
(*c*) Straight chain molecules of $\mathbf{C_{13}H_{28}}$ occur in the kerosene fraction. Upon cracking a molecule of $\mathbf{C_{13}H_{28}}$, a $\mathbf{C_2H_4}$ molecule, a $\mathbf{C_4H_8}$ molecule and an unbranched alkane molecule are obtained.
Identify this unbranched alkane molecule and state its octane number.
Draw structures for three of the isomers of $\mathbf{C_4H_8}$. (15)
(*d*) Name two other processes carried out in oil refineries to modify hydrocarbon structures. (6)
(*e*) The combustion of one of the $\mathbf{C_4H_8}$ isomers is described by the following balanced equation.

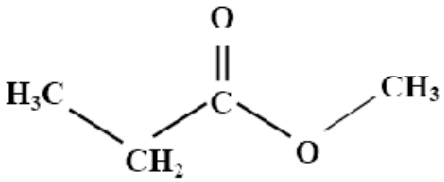
$$\mathbf{C_4H_8 + 6O_2 \longrightarrow 4CO_2 + 4H_2O \quad \Delta H = -2710\ kJ\ mol^{-1}}$$

The standard heats of formation of water and carbon dioxide are –286 and –394 kJ mol^{-1}, respectively.
Calculate the heat of formation of this $\mathbf{C_4H_8}$ isomer. (12)

Families of Organic Compounds

2004 Question 7

(*a*) Copy into your answer book the structure of the ester shown and indicate clearly on your diagram a carbon atom which is in planar geometry in the molecule, and also a carbon atom which is in tetrahedral geometry in the molecule. (8)



(*b*) Give the names of the alcohol and of the carboxylic acid from
which the ester shown in the diagram is synthesised. What organic reaction type describes this esterification reaction? (15)

(*c*) The carboxylic acid you were asked to name in (*b*) may itself be synthesised in two steps from an alcohol.

(*i*) Identify the alcohol from which the carboxylic acid is derived.
(*ii*) Give the name and structure of the intermediate organic compound in this synthesis.
(*iii*) Identify the type of organic reaction involved in each step.
(*iv*) Identify the inorganic reagents which may be used in this synthesis. (21)

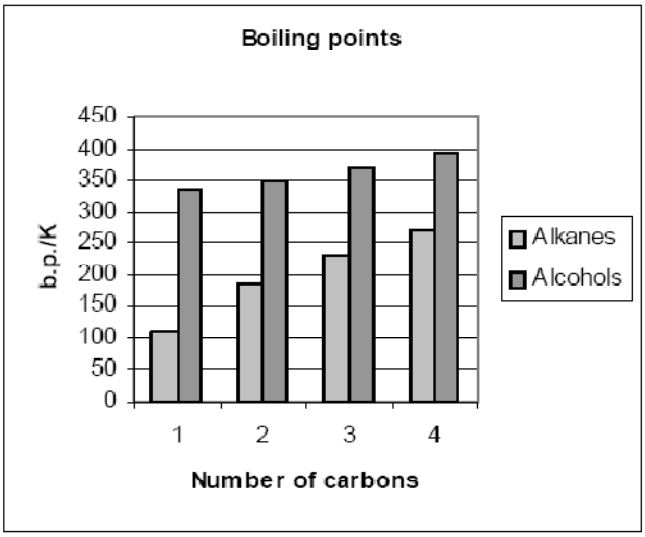
(*d*) State **two** common uses of esters. (6)

2006 Question 4 (j)

Which class of organic compound is responsible for the odour associated with fruits such as apples, oranges, pears, bananas and strawberries?

2006 Question 10 (c)

The chart compares the boiling points of alkanes and primary alcohols containing from one to four carbon atoms.



(*i*) Give **two** reasons why each of these alcohols has a higher boiling point than the corresponding alkane. (7)

(*ii*) Explain why the difference in boiling points between methane and methanol is 226.5 K while the difference in boiling points between butane and butanol is only 119 K. (6)
(*iii*) Describe, in general terms, the solubilities of methane, methanol, butane and butanol in water. (12)

2007 Question 4 (g)

Name and draw the structure of a carboxylic acid that is widely used as a food preservative.

2009 Question 4(h)

Draw the structures of two acidic functional groups that occur in organic compounds.

2009 Question 8

Answer the questions below with reference to the compounds **A** – **D** in the table on the right.

A	C_2H_5OH
B	CH_3CHO
C	CH_3COOH
D	$CH_3COOC_2H_5$

(*a*) Give the IUPAC name for each of the compounds **A** – **D**. (12)

(*b*) Name the family (homologous series) of organic compounds to which compound **B** belongs. Name the aromatic compound, found in almond kernels, that has the same functional group as compound **B**. (9)

(*c*) Which of the compounds **A** – **D** is present in concentrations of about 40% (v/v) in whiskey? Which of the other compounds is formed as the primary metabolite of this compound in the human body? (6)

(*d*) Describe what is observed when a small amount of sodium carbonate is added to a test tube containing an aqueous solution of compound **C**. Write a balanced equation for the reaction.
Name the flavouring agent that consists of an approximately one molar solution of compound **C**.
Express the concentration of a one molar solution of **C** in terms of % (w/v). (15)

(*e*) Draw the full structural formula for compound **D** and clearly label each carbon atom that has tetrahedral geometry. (8)

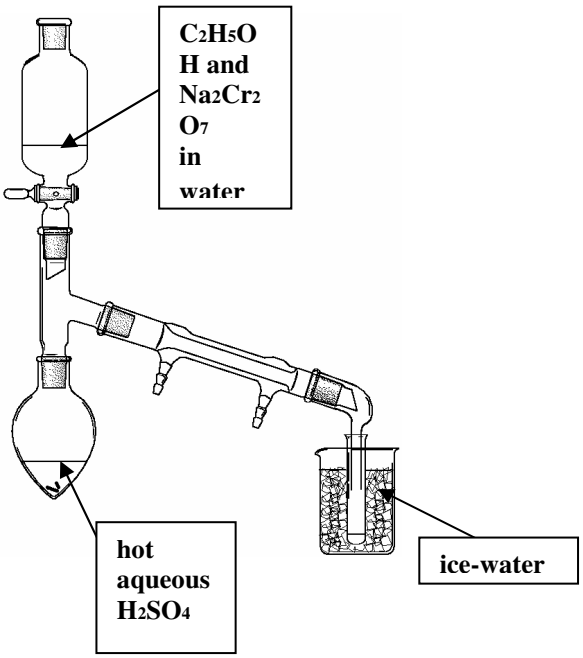
Types of Reaction in Organic Chemistry

2005 Question 2

A group of students prepared ethanal (**CH_3CHO**) by slowly adding an aqueous solution of ethanol (**C_2H_5OH**) and sodium dichromate(VI) (**$Na_2Cr_2O_7.2H_2O$**) to a hot aqueous solution of sulfuric acid (**H_2SO_4**). The apparatus drawn below was used. The reaction is described by the following equation.

$3C_2H_5OH + Cr_2O_7 + 8H^+ \rightarrow 3CH_3CHO + 2Cr + 7H_2O$

(*a*) Why was the receiving vessel cooled in ice-water? (5)
(*b*) State **two** features of the preparation that are necessary to maximise the yield of ethanal and, for each feature stated, explain why it is necessary. (12)
(*c*) Describe and account for the colour change which is observed during the addition of the ethanol and sodium dichromate(VI) solution to the hot acid. (9)
(*d*) Describe how you would carry out Fehling's test on a sample of ethanal. What observation would you expect to make in this test? (12)
(*e*) Assuming that all of the features needed to maximise the yield of ethanal were present, what mass of ethanal would be produced in the preparation if the students used 8.94 g of sodium dichromate(VI) (**$Na_2Cr_2O_7.2H_2O$**), and a 75% yield was obtained? (12)



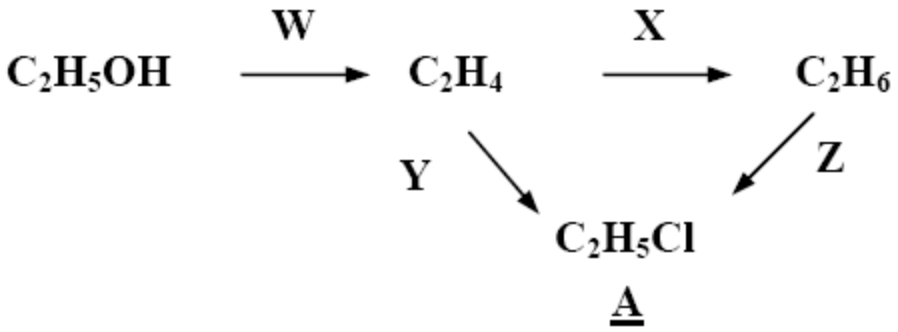
2005 Question 4 (j)

Complete and balance the following equation:

$C_2H_5OH + Na \rightarrow$

2005 Question 7

Examine the reaction scheme and answer the questions which follow.



(*a*) Name the compound labelled **A**. (5)
(*b*) For each of the conversions **W**, **X**, **Y** and **Z**, classify it as an *addition*, an *elimination* or a *substitution* reaction. (12)
(*c*) Describe with the aid of a labelled diagram how the conversion **W** may be carried out in a school laboratory and how a sample of the product may be collected. How would you test this product to show that it is unsaturated? (18)
(*d*) The conversion labelled **Z** is known to occur by a *free radical* mechanism.
State **three** clear pieces of experimental evidence which support this mechanism. (15)

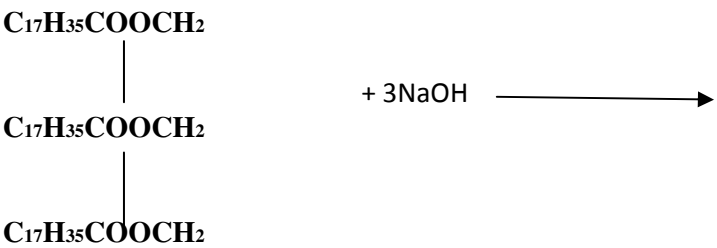
2005 Question 10 (c)

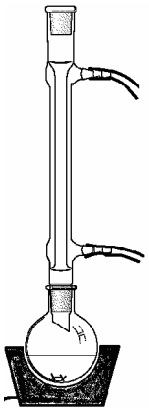
State the principle on which all chromatographic separation techniques are based. (10)

Describe with the aid of clearly labelled diagrams how you could carry out an experiment to separate a mixture of dyes (or indicators) using paper, thin-layer or column chromatography. (15)

2006 Question 2

A sample of soap was prepared in the laboratory by refluxing a mixture of approximately 5 g of animal fat, 2 g of sodium hydroxide pellets (an excess) and 25 cm^3 of ethanol in an apparatus like that drawn on the right.





Glyceryl tristearate

(*a*) Why was the reaction mixture refluxed? Name the *type* of reaction which occurs during the reflux stage of the preparation. (8)
(*b*) Complete and balance the equation below for the reaction between glyceryl tristearate, an animal fat, and sodium hydroxide. (9)
(*c*) What is the purpose of the ethanol? Why is it desirable to remove the ethanol after reflux? Describe with the aid of a labelled diagram how you would remove the ethanol after the reflux stage of the experiment. (12)
(*d*) Describe how a pure sample of soap was obtained from the reaction mixture. (9)
(*e*) At the end of the experiment, what is the location
(*i*) of the second product of the reaction,
(*ii*) of the excess sodium hydroxide? (6)
(*f*) What would you observe, upon shaking, if a little of the soap prepared in this experiment is added to (*i*) a test tube containing deionised water,
(*ii*) a test tube containing mineral water from a limestone region? (6)

2006 Question 4 (g)

What observation is made when a sample of ethanal is heated with Fehling's reagent?

2006 question 9 (c)

Describe the mechanism for the bromination of ethene. (9)

State and explain **one** piece of experimental evidence to support this mechanism. (6)

2006 Question 2

A sample of ethanoic acid (**CH_3COOH**) was prepared by the oxidation of ethanol using the apparatus shown. The reaction is exothermic and is represented by the following equation:

$$3C_2H_5OH + 2Cr_2O_7^{2-} + 16H^+ \rightarrow 3CH_3COOH + 4Cr^{3+} + 11H_2O$$

(*a*) Before heating the reaction flask, the ethanol and water were added from the tap funnel.
State **two** precautions which should be taken when carrying out this addition in order to avoid excessive heat production. (8)

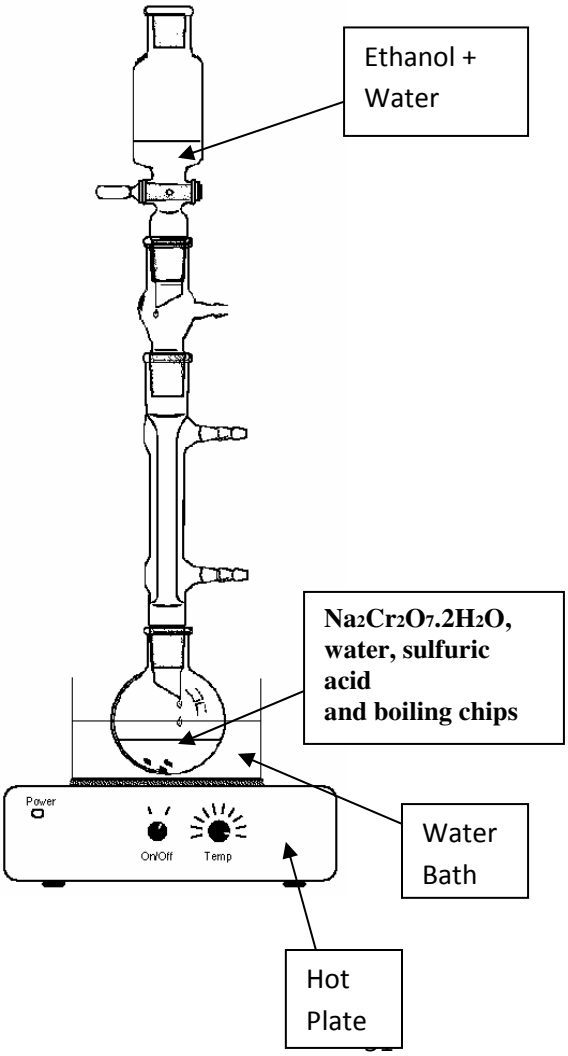
(*b*) Describe and explain the colour change observed in the reaction flask as the ethanol was oxidised. (9)

(*c*) What was the purpose of heating the reaction mixture under reflux after the addition from the tap funnel was complete? (6)

(*d*) Show clearly that the ethanol was the limiting reagent when 8.0 cm^3 of ethanol (density 0.80 g cm^{-3}) was added to 29.8 g of sodium dichromate, **$Na_2Cr_2O_7.2H_2O$.**
There was excess sulfuric acid present. (12)

(*e*) Describe how the ethanoic acid product was isolated from the reaction mixture. (6)

(*f*) Describe your observations when a small quantity of solid sodium carbonate was added to a sample of the ethanoic acid produced. Write a balanced chemical equation for the reaction which occurred. (9)



2007 Question 4 (j)

Ultraviolet absorption spectroscopy can be used in the quantitative analysis of some organic compounds (e.g. drug metabolites and plant pigments). What is the underlying principle of this analytical technique?

2007 Question 8

Study the reaction scheme and answer the questions which follow.

$$\underset{\textbf{A}}{C_2H_4} \rightleftharpoons \underset{\textbf{B}}{C_2H_5OH} \rightleftharpoons \underset{\textbf{C}}{CH_3CHO}$$

(*a*) Name the homologous series (*i*) to which **A** belongs, (*ii*) to which **C** belongs. (8)
(*b*) The conversion of **B** to **A** is an elimination reaction. What two features of elimination reactions are illustrated by this conversion? (6)
(*c*) Name the reagent and the catalyst required to convert **C** to **B**. (6)
(*d*) Draw full structural formulas for **B** and **C**. Indicate any carbon atom in either structure that has planar geometry. List the bonds broken in **B** and the bond made in **C** in the synthesis of **C** from **B**. (18)
(*e*) After carrying out a laboratory conversion of **B** to **C**, how could you test the product to confirm the formation of **C**? (9)
(*f*) Compound **C** is formed as a metabolite of compound **B** in the human body. How does compound **B** come to be present in the body?(3)

2007 Question 11 (b)

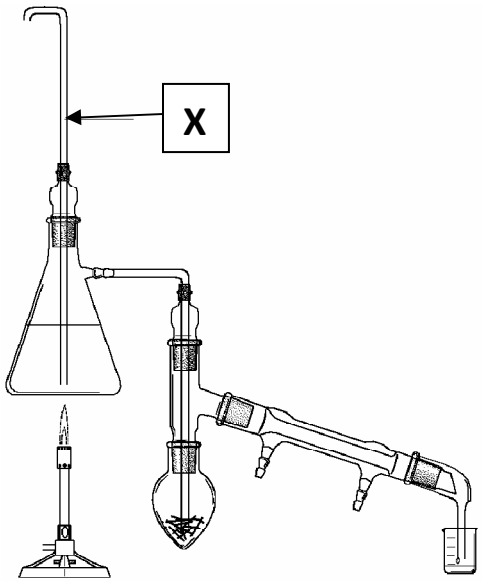
An equimolar mixture of chlorine and methane react together at room temperature only when ultraviolet light is present.
(*i*) Explain clearly the role of the ultraviolet light in the reaction between chlorine and methane. (7)
(*ii*) Name the two main products of the reaction between chlorine and methane. (6)
(*iii*) Account for traces of ethane found in the product mixture. (6)
Chlorine reacts with ethene at room temperature even in the dark.
(*iv*) Name the type of mechanism which occurs in the reaction between chlorine and ethene. (3)
(*v*) Give a use for chloroalkanes. (3)

2008 Question 2

Chromatography is widely used in chemistry as a separation technique.
(*a*) Describe, with the aid of clearly labelled diagrams, how you would set up and carry out an Experiment to separate the components in a mixture of indicators using paper chromatography, thin-layer chromatography or column chromatography. (15)

(*b*) Explain why the different components of the mixture travel different distances along the paper or along the thin-layer or through the column in a given time. (6)

Steam distillation, using an apparatus like that shown, is a technique used to isolate an organic substance from plant material. The principle of this technique is that the boiling point of a mixture of two *immiscible liquids* is below the boiling points of both pure liquids. This allows the organic substance to be isolated at temperatures below 100 ºC and avoids the delicate organic molecules being damaged at high temperatures.



(*c*) What is meant by the term *immiscible liquids*? (3)
(*d*) Name a substance you isolated by steam distillation in the school laboratory and the plant material from which it was extracted. (6)
(*e*) Explain the function of the tube labelled **X**. (6)
(*f*) Describe the appearance of the distillate collected. Name or describe briefly a technique that could be used to separate the organic substance from the water. (9)
(*g*) In a steam distillation experiment 20.0 g of plant material were heated in the presence of steam. Only 0.250 g of pure organic liquid was obtained. Calculate the percentage yield. (5)

2008 Question 4 (i)

Complete and balance the equation:

C_2H_5OH + Na $\longrightarrow$

2008 Question 8 (d) + (e)

(*d*) The ionic addition mechanism for the reaction of ethene with bromine water involves the formation of an intermediate ionic species. Draw the structure of this species.
Give the names or structural formulas of the three products that would be formed if the bromine water used in the reaction contained sodium chloride.
How does the formation of these three products support the mechanism of ionic addition? (18)
(*e*) Name the polymer formed when ethene undergoes addition polymerisation.
Draw **two** repeating units of this polymer. (6)

2008 Question 11 (a)

(*a*) Alcohols can be obtained by the reduction of aldehydes and ketones using hydrogen and a suitable catalyst.
(*i*) Name a suitable catalyst for these reduction reactions. (4)
(*ii*) Name the alcohol produced when propanal (**C_2H_5CHO**) is reduced. (3)
(*iii*) Draw the structure of the alcohol produced when propanone (**CH_3COCH_3**) is reduced. To which class (primary, secondary or tertiary) of alcohols does it belong? (6)
(*iv*) Which of the two compounds, propanal or propanone, would be oxidised by warm Fehling's solution? Give the name *and* structure of the organic product of the oxidation reaction. (9)
(*v*) Give **one** common use for propanone. (3)

2009 Question 4 (i)

Complete and balance the equation: $C_2H_6 + Cl_2 \xrightarrow{\text{uv light}}$

Options

2004 Question 4 (k)

Answer part **A** or **B**.
A How is oxygen gas produced industrially?
or
B How does the anodising of aluminium protect it from corrosion?

2004 Question 11 part c

(*c*) Answer either part **A** or part **B**.

A
Write a brief note on the contribution made to our
understanding of crystal structures by
(*i*) Lawrence and William Bragg,
(*ii*) Dorothy Hodgkin. (7)
What type of crystal is formed by iodine and what are the
binding forces in the crystal? (6)
Explain
(*i*) why metals are generally good conductors of electricity,
(*ii*) why most ionic crystals dissolve in water. (12)

or

B
The *greenhouse effect* is a natural phenomenon but its effects have been enhanced by human activity over the past 200 years.
(*i*) Explain the term *greenhouse effect*. (7)
(*ii*) Identify **one** gas in the atmosphere which makes a significant contribution to the greenhouse effect. (3)
(*iii*) In relation to the gas you have identified in (*ii*), mention a type of human activity which has been a major contributor to the increased levels of this gas in the atmosphere. (3)
(*iv*) Identify **one** gas, found in the atmosphere, which is not a greenhouse gas. (3)
(*v*) State **three** probable consequences of an increased greenhouse effect which have been suggested by environmental scientists. (9)

2005 Question 4 (k)

Answer part **A** or **B**.
A Describe using chemical equations the chain reaction process whereby chlorine free radicals break down ozone in the stratosphere.
Or
B How does a sacrificial anode protect a metal from corrosion?

2005 Question 11

Answer either part **A** *or* part **B**.

A

(*i*) What is meant by the term *addition polymerisation*? (7)
(*ii*) Name the Du Pont chemist pictured on the right who discovered poly(tetrafluoroethene), PTFE. (3)
(*iii*) Describe using an equation how poly(tetrafluoroethene) is produced from its monomers. (9)
(*iv*) Give **two** common uses of PTFE. (6)

or

B

(*i*) Account for the inert nature of nitrogen gas. (7)
(*ii*) What is meant by *nitrogen fixation*?
State **two** ways by which nitrogen is fixed in nature. (9)
(*iii*) The concentration of $\mathbf{NO_2}$ in the atmosphere has increased in the past fifty years. Describe with the aid of chemical equations how an increase in the number of cars has contributed to this change. (9)

2006 Question 4 (k)

Answer part **A** or part **B**.
A State **two** uses of nitrogen gas based on its chemical stability.
or
B Name **two** metals, one a main group metal, the other a transition element, both of which are protected from further corrosion by the oxide layer which forms on their surfaces.

2006 Question 11 (c)

Answer part **A** *or* part **B**

A

Select **one** of the manufacturing processes below and answer the questions which follow:
ammonia manufacture nitric acid manufacture magnesium oxide manufacture
(*i*) What are the raw materials for the manufacturing process you have chosen? Describe how the raw materials are treated before they become the feedstock for the manufacturing process. (12)
(*ii*) Name **one** product of the process you have chosen, which, if discharged, could cause pollution. (3)
(*iii*) State the most important use of the *main* product of the process you have chosen.
What makes this product particularly suitable for this use? (10)

or

B

A blast furnace may be used in the extraction of iron from iron ore.
(*i*) What materials must be added to a blast furnace in operation? (12)
(*ii*) Name the principal reducing agent in the blast furnace and write a balanced equation for its reaction with haematite ($\mathbf{Fe_2O_3}$). (9)
(*iii*) Why is the pig iron produced in a blast furnace further processed into steel? (4)

2007 Question 4 (k)

Answer part **A** or **B**.
A The use of CFCs as refrigerant gases has been discontinued. Name a group of substances used to replace CFCs as refrigerant gases.
or
B Name the electrochemist who was the first to isolate the elements sodium and potassium in 1807 by passing electricity through sodium hydroxide and potassium hydroxide, respectively.

2007 Question 11 (c)

Answer either part **A** *or* part **B**.
A
Environmentalists are concerned about the increasing abundance of carbon dioxide in the atmosphere.
(*i*) State one important way carbon dioxide is constantly added to the atmosphere. (4)
(*ii*) Carbon dioxide is a greenhouse gas. It has been assigned a greenhouse factor of 1.
What use is made of the *"greenhouse factor"* of a gas? (6)
(*iii*) Name **two** other greenhouse gases. (6)
(*iv*) Carbon dioxide is removed from the atmosphere when it dissolves in rainwater, seas, lakes, etc.
What **three** chemical species arise in water as a result of carbon dioxide gas dissolving in it? (9)
or
B
Aluminium, sodium chloride and graphite are all crystalline solids.
For each of these substances, name the type of crystal formed. (7)
Explain clearly, in terms of bonding, why
(*i*) aluminium is a good conductor of electricity,
(*ii*) sodium chloride is soluble in water,
(*iii*) graphite is soft and slippery. (18)

2008 Question 4 (k)

Answer part **A** or part **B**.

A State the **two** main ways by which nitrogen is fixed in nature.
Or
B State **two** ways in which steel differs from the iron produced in a blast furnace.

2008 Question 11 (c)

A
In 2007 former US Vice-President Al Gore and the UN Climate Change Committee were awarded the Nobel Peace Prize for their work in highlighting climate change.
Al Gore has stressed the need to control global carbon dioxide emissions.
Carbon dioxide is a *greenhouse gas* and an *acidic oxide*.

(*i*) Explain the underlined terms. (7)
(*ii*) State **two** major ways by which human activities contribute to the addition of carbon dioxide to the atmosphere. (6)

(*iii*) Carbon dioxide is removed from the atmosphere when it dissolves in rainwater, in seas, in lakes, etc. What three chemical species form as a result of carbon dioxide gas dissolving in water? (9)
(*iv*) Acidic oxides can be removed from waste gases by scrubbers in chimneys before the gases are released into the atmosphere. Name a reagent used in scrubbers to remove acidic oxides. (3)

or

B

(*i*) Name the ore from which aluminium is extracted. What substance is used to convert this ore into a soluble aluminium compound in the first stage of the extraction? (7)
(*ii*) Write balanced equations for the reactions taking place at the positive and negative electrodes in the electrolysis of alumina. (12)
(*iii*) What is the function of cryolite (**Na_3AlF_6**) in the electrolysis of alumina? (3)
(*iv*) Why is recycling of aluminium metal important for the protection of the environment? (3)

2009 Question 4 (k)

Answer part **A** or part **B**.

A What use is made of the organometallic catalysts discovered by Karl Ziegler in 1953?

Or

B Write a balanced chemical equation for **one** of the following reactions from syllabus case studies based on the chemical industry:
(*i*) the synthesis of urea from ammonia;
(*ii*) the combustion of ammonia in air;
(*iii*) the formation of magnesium hydroxide from slaked lime and seawater.

2009 Question 11(c)

Answer either part **A** *or* part **B**.

A

(*i*) Why can very electropositive metals such as sodium only be extracted from their ores by electrolysis? (4)
(*ii*) Explain why the electrolyte used in the Downs cell is molten.
What is the purpose of the calcium chloride used in the process? (6)
(*iii*) Write a balanced equation for overall reaction in the Downs cell.
Explain how the products are prevented from recombining after they have been formed by electrolysis.
Give **one** commercial use for each product. (15)

or

B

Write balanced chemical equations showing
(*i*) the formation of ozone in the stratosphere,
(*ii*) the photodissociation of ozone. (10)
CFCs are a group of substances known to have caused damage to the ozone layer.
(*iii*) State two effects of damage to the ozone layer.
(*iv*) Give one former major use of CFCs.
(*v*) Give an example of a CFC.

(*vi*) Identify the group of compounds now used as ozone friendly CFC replacements. (15)

Ordinary Level Chemistry Exam Questions By Topic 2004 - 2009

General

2009 Question 10(a)

Le Châtelier, **Rutherford**, **Arrhenius**, **Dalton** and **Marie Curie** all made important contributions to scientific knowledge. In your answer book match the names of these scientists with the letters **A – E** that correspond in the table below to their contribution to scientific knowledge. (5 x 5)

A	*Stated that matter consists of tiny, indivisible particles called atoms.*
B	*Stated that chemical reactions at equilibrium oppose applied stresses.*
C	*Discovered the nucleus of the atom.*
D	*Isolated the radioactive elements, polonium and radium.*
E	*Defined an acid as a substance that produces hydrogen ions in aqueous solution.*

The Atom

2004 Question 4 (a)

Name the scientist who discovered the nucleus of the atom.

2005 Question 5

Each of the following were important contributors to what we know about atomic structure, the elements or
radioactivity.

Bohr **Becquerel** **Curie** **Dalton** **The Greeks** **Moseley** **Thomson** **Rutherford**

Select from the list above one answer to each of the following.

(*a*) Who proposed the early theory that matter consists of the four elements: earth, air, fire and water? (7)
(*b*) Who described atoms as small indivisible particles? (7)
(*c*) Who identified electrons as sub-atomic particles? (6)
(*d*) Who is credited with the discovery of the nucleus of the atom? (6)
(*e*) Who proposed a model for the atom in which the electrons circulated around the nucleus in fixed energy levels or orbits? (6)
(*f*) Who discovered that uranium salts emitted radiation? (6)
(*g*) Who received a Nobel Prize for the isolation of the elements polonium and radium? (6)
(*h*) Whose determination of the charge on the nucleus of atoms allowed the systematic arrangement of the elements in the modern periodic table? (6)

2006 Question 4 (f)

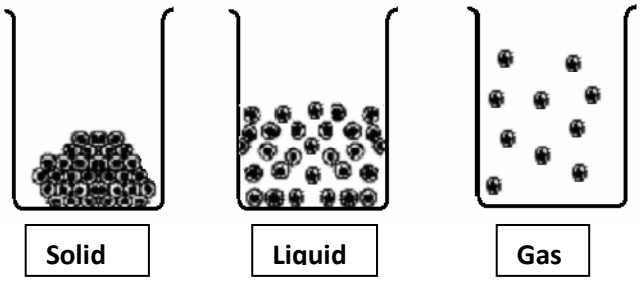
Name the English scientist pictured on the right who identified electrons as negatively charged subatomic particles in the 1890s.

2006 Question 5 (a) + (b)

(*a*) Define (*i*) *atomic number,* (*ii*) *relative atomic mass*. (11)
(*b*) The two best-known isotopes of carbon are carbon-12 and carbon-14.
(*i*) What term is used in chemistry for the numbers (e.g. 12 and 14 in the case of carbon above) used to identify particular isotopes of an element? (6)
(*ii*) Name the subatomic particle that is responsible for the difference between carbon-12 and carbon-14. How many of these particles are found in an atom of carbon-14? (6)

2006 Question 11 (a)

The diagrams illustrate the arrangement of particles in the three states of matter.



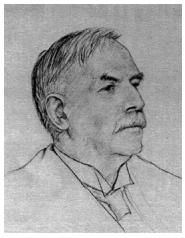
(*i*) Outline briefly the differences between the three states in terms of the movement of their particles. (9)

(*ii*) What do you understand by *diffusion*? (6)

(*iii*) Describe a simple experiment to demonstrate diffusion. (10)

2007 Question 5 (c)

The scientist shown in the bottom picture discovered the nucleus of the atom by bombarding thin sheets of a particular element with alpha particles from a radioactive source.
(*i*) Name this scientist. (6)
(*ii*) Name the element he bombarded with alpha particles. (6)



Discovered nucleus

2007 Question 11 (a)

(*a*) The following names are associated with the development of our knowledge of elements. Write in your answer-book the omitted name corresponding to each number 1 to 5.

Mendeleev **Dalton** **The Greeks** **Bohr** **Davy**

In ancient times **<u>1</u>** suggested that everything that exists was formed from the four elements:

earth, air, fire and water. In the early 1800s **2** suggested that atoms were tiny indivisible particles. By the use of electrolysis **3** isolated elements such as sodium and potassium. By arranging the elements in order of increasing relative atomic mass (atomic weight) and by placing similar elements in groups **4** produced a systematic arrangement (an early periodic table) of the elements known to him. From looking at atomic spectra **5** came up with the theory that electrons moved around the nucleus of an atom in fixed energy levels (orbits). (5 × 5)

2008 Question 4 (f)

Name the English scientist pictured on the right who identified, in the 1890s, electrons as negatively charged subatomic particles.

2008 Question 5 (a)

(*a*) Atoms are made up of protons, neutrons and electrons.
(*i*) Copy the following table into your answer book and fill in the missing information. (17)

	Relative mass	**Relative charge**	**Location**
Proton	1		
Neutron			nucleus
Electron	1/1836	– 1	

(*ii*) What information about subatomic particles is given by the atomic number of an element? (6)

2008 Question11 (a)

The following names are associated with the development of our knowledge of the elements and atomic structure. Choose a name from this list when answering the questions below.

Boyle Curie Dalton Mendeleev Rutherford

(*i*) Who was the Co. Waterford-born scientist who gave us an important gas law and is described as "*the father of modern chemistry*"?
(*ii*) Who was the English schoolteacher who in 1808 described atoms as *"small indivisible particles"*?
(*iii*) Identify the Russian scientist who produced an early version of the periodic table of the elements.
(*iv*) Who was the Polish born scientist who received the Nobel Prize in 1911 for isolating the radioactive elements polonium and radium?
(*v*) Who is credited with the discovery of the nucleus of the atom?

2009 Question 4(a) + (b)

What are the three states of matter?

The Greek philosopher Empedocles (pictured on the right) suggested there were four “elements”. One of these “elements” was earth. Name **two** of the other three “elements” according to the Greeks.

2009 Question 5 (a)

(*a*) Define *atomic number*. (8)
In 1913, atomic numbers were introduced by the young English scientist pictured on the right. Two years later he was killed in action at Gallipoli during World War I. Who was he? (6)

Arrangement of Electrons in the Atom

2004 Question 10 (c)

Protons, neutrons and electrons are located in the atom.
Copy the table below into your answer book and fill in the missing information. (13)

	Relative mass	**Relative charge**	**Location**
Proton	1		
Electron	1/1840		Outside the nucleus
Neutron		0	In the nucleus

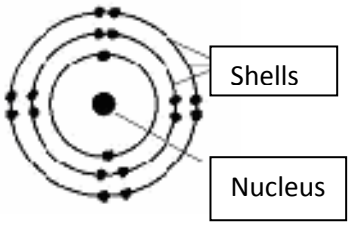
Define *atomic number*. (6)
State the arrangement of electrons in the main energy levels in an atom of potassium. (6)

2005 Question 4 (g)

Write the arrangement of the electrons in the main energy levels of a calcium atom.

2006 Question 4 (a)

The diagram on the right shows the arrangement of electrons in main energy levels (shells) for an atom of a particular element. Identify the element.



2007 Question 5 (a)

How many (*i*) protons, (*ii*) neutrons, are there in an atom of potassium-39?

(*iii*) How are the electrons arranged in shells in this atom?

(*iv*) What is the valency of potassium? (15)

[See Mathematics tables p. 44.]

2008 Question 3

Flame tests can be used to identify the metallic element present in a salt.

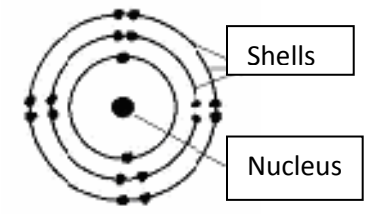
(*a*) Copy the table below into your answer book and complete it, matching the correct salt from the list on the right with the colour it imparts to a Bunsen flame. (14)

FLAME COLOUR	Orange-yellow	Lilac	Green
SALT			

(*b*) Describe how you could carry out a flame test using one of these salts. (18)
(*c*) Where, outside the laboratory, would you be likely to see lights containing sodium vapour? (6)
(*d*) Some fireworks produce red light in the sky.
Name a metal whose salts are used in the manufacture of fireworks that produce red light. (6)
(*e*) What test could you carry out to confirm the presence of chloride ions in aqueous solution? (6)

2008 Question 4 (a)

The diagram on the right shows the arrangement of electrons in main energy levels (shells) for an atom of a particular element. Identify the element.



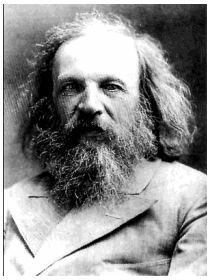
2009 Question 8(c)

In the case of any **four** of the following, describe simple experiments, one in each case,
(*c*) to show the presence of potassium in potassium chloride using a flame test,

The Periodic Table

2005 Question 4 (a)

Name the Russian scientist pictured on the right who proposed an early version of the periodic table in 1867.



Chemical bonding and Chemical Formulas

2004 Question 4 (d)

State **two** characteristic properties of ionic substances.

2004 Question 5

The following words are omitted from the passage below:

electronegativity **polar pair**

water **non-polar** **boiling points**

Write in your answer book the omitted words corresponding to each of the numbers 1 to 6. (36)

A covalent bond is formed when a _____1_____ of electrons is shared between the bonding atoms. When the electrons are shared equally, a _____2_____ covalent bond is formed, but when one atom has a greater attraction for the bonding electrons, a _____3_____ covalent bond is formed. Most covalent compounds have low _____4_____ and do not dissolve very well in _____5_____. The nature of chemical bonds can be predicted using _____6_____ values.

Draw a dot and cross diagram to describe the bonding in methane (**CH_4**). (9)
What is the shape of the methane molecule? (5)

2005 Question 4 (c)

Define *electronegativity*.

2005 Question 7

(*a*) What is meant by (*i*) an *ionic bond*, (*ii*) a *covalent bond*? (8)
(*b*) Describe using dot and cross diagrams the bond formation in
(*i*) water (**H_2O**), (*ii*) sodium chloride (**NaCl**). (18)
(*c*) What is the shape of the water molecule? (6)
(*d*) What colour would a sample of sodium chloride impart to a Bunsen flame? (6)
(*e*) The diagram shows a thin stream of water flowing from a suitable piece of equipment. What would be observed if a charged rod was held close to the stream of water?
What property of water does this experiment demonstrate? (12)

2006 Question 5 (c)

Define *electronegativity*. (6)

Use electronegativity values (Mathematics Tables, page 46) to predict the type of bond (ionic, polar covalent or non-polar) likely to be formed between each of the following pairs of elements.
*(*i) carbon and sulfur, (ii) potassium and fluorine, (iii) hydrogen and chlorine. (9)

2006 Question 6 (c)

Words or phrases are omitted from the passage below.

Write in your answer book suitable words or phrases corresponding to the numbers **1** to **4**.

To purify a sample of benzoic acid, the impure crystals were dissolved in the ___ **1** _ of hot water.

The hot solution was filtered to remove the _ **2** _ impurities. The filtrate was allowed to cool and,

when crystals had formed, they were removed from the solution by filtration, leaving the ____**3**____

impurities behind. This method of purification of a solid is known as **4** . (24)

2006 Question 10 (a)

(*i*) Describe using a dot and cross diagram the bonding in a molecule of ammonia (**NH_3**). (10)
(*ii*) What is the shape of the ammonia molecule? (6)
(*iii*) Would you expect ammonia gas to be soluble or insoluble in water?
Give a reason for your answer. (9)

2007 Question 4 (a)

State the shape of the water molecule.

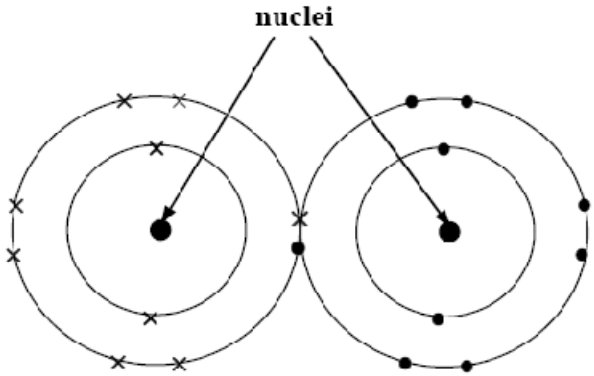
2007 Question 7

The bond between the chlorine atoms in a chlorine molecule (**Cl_2**) is a pure (non-polar) covalent bond, whereas the bond between the chlorine atom and the hydrogen atom in the hydrogen chloride molecule (**HCl**) is a polar covalent bond. The bond between chlorine and sodium in sodium chloride (**NaCl**) is an ionic bond.
(*a*) Define (*i*) *covalent bond*, (*ii*) *ionic bond*. (8)
(*b*) Draw dot and cross diagrams showing the formation of the bonds in (*i*) **Cl_2**, (*ii*) **HCl**, (*iii*) **NaCl**. (18)
(*c*) What is meant by a *polar bond*? Explain why the bond in the **HCl** molecule is polar. (9)
(*d*) Which of the substances, chlorine or sodium chloride, would you expect to be more soluble in water? Give a reason for your answer. (9)
(*e*) Hydrogen chloride dissolves readily in water to give a solution which is found in gastric juice in the stomach, and which is also commonly used in the school laboratory. Name the solution. (6)

2008 Question 5 (b) + (c)

(*b*) (*i*) Define *electronegativity*. (6)
(*ii*) How are electronegativity values used to predict the type of bonding present in a compound? (6)

(*c*) The diagram on the right shows the bonding in a fluorine molecule, **F_2**. Dots (•) and crosses (×) represent the electrons.



(*i*) What type of chemical bond is found between the fluorine atoms in a fluorine molecule? (6)

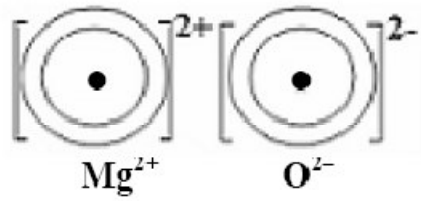
(*ii*) Name another type of chemical bond formed by fluorine.
Give an example of a compound in which fluorine forms this type of bond. (9)

2009 Question 4 (e)

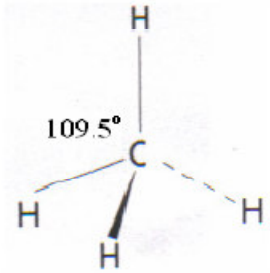
Define *electronegativity*.

2009 Question 5 (b) +(c)

(*b*) What is an *ionic bond*? (6)
The diagram on the right is an incomplete illustration of the ionic bond between magnesium and oxygen.
How many protons are there (*i*) in the nucleus of the magnesium ion,
(*ii*) in the nucleus of the oxide ion?
Copy the diagram into your answer book.
Use dots and crosses to show the electrons present in each of the four shells. (12)
Give any **two** characteristic properties of ionic compounds. (6)



(*c*) The diagram on the right shows the methane molecule in which all four bond angles are identical.
What term is used to describe the shape of this molecule?
What type of bonds are present in the molecule?
Give the name *or* molecular formula of any other simple molecule
And draw the shape of its molecules *or* give the term that describes the shape. (12)



2009 Question 8(d)

In the case of any **four** of the following, describe simple experiments, one in each case,
(*e*) to show that water is a polar liquid whereas cyclohexane is non-polar (diagram required).

Chemical Equations and tests for Anions

2007 Question 4 (h)

How would you test for the presence of sulfate ions in aqueous solution?

2009 Question 8(d)

In the case of any **four** of the following, describe simple experiments, one in each case,
(*d*) to test for the presence of sulfate ions in aqueous solution,

Trends in the Periodic Table

2004 Question 4 (c)

What is the trend in the size of atomic radii across a period of the periodic table?

2006 Question 4 (c)

What is the trend in the size of atomic radii going down any group of the periodic table?

2008 Question 4 (c)

What is the trend in the size of atomic radii going down
the first group of the periodic table?

2009 Question 4 (d)

Explain why atomic radius decreases across a period in the periodic table.

Radioactivity

2004 Question 4 (b)

State **one** use of the radioisotope ^{60}Co (cobalt-60).

2005 Question 4 (b)

Describe the nature (composition) of an alpha-particle (α-particle).

2006 Question 5 (b) (iii)

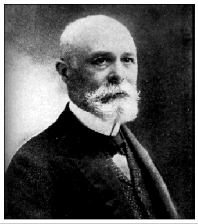
Carbon-14 is radioactive and is an emitter of β-particles (beta-particles). Explain what a β-particle is. Give **one** use of carbon-14. (12)

2007 Question 5 (b)

In November 2006, a former Soviet agent, Alexander Litvinenko, died in London. The cause of his death was identified as radiation poisoning due to polonium-210.

(*i*) Name the French scientist who discovered radioactivity in 1896. (5)
(*ii*) Name the Polish born scientist who received the Nobel prize in 1911 for the isolation of the radioactive elements polonium and radium. (6)
(*iii*) Polonium-210 decays with a half-life of 138 days by emitting alpha particles. What is meant by the term *half-life*? What are *alpha particles*? (12)

Litvinenko



French scientist

Isolated polonium

2009 Question 10(b)

The French scientist, pictured on the right, discovered radioactivity while experimenting with uranium salts.
(*i*) Name the French scientist. (4)
(*ii*) What is *radioactivity*? (6)
(*iii*) Name one type of radiation emitted by radioactive substances. Describe its penetrating ability in air, and state its charge, if any. (9)
(*iv*) Give an example of a radioactive isotope and state **one** of its uses. (6)

The Mole Concept

2004 Question 10 (b)

Define *relative atomic mass*. (7)
Calculate the relative molecular mass of sulfuric acid (**H_2SO_4**) from the relative atomic masses of its elements. (6)

Properties of Gases

2004 Question 4 (e)

What is the volume in litres of 6×10^{23} gaseous molecules at standard temperature and pressure?

2007 Question 4 (b)

What is the mass of 11.2 litres of methane (**CH_4**) gas at s.t.p.?

2009 Question 11(b)

(*i*) State *Boyle's law*. (7)
(*ii*) A sample of carbon dioxide gas has a volume of 12230 cm^3 at a temperature of 298 K and a pressure of 2×10^5 Pa. Use the combined gas law

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

to calculate the volume occupied by the gas at a temperature of 273 K and a pressure of 1×10^5 Pa.(9)

(*iii*) Taking the values 273 K and 1×10^5 Pa in (*ii*) as standard temperature and pressure, how many moles of gas are in the sample? (6)
(*iv*) How many molecules are in the sample? (3)

Stoichiometry

2004 question 4 (g)

The label on a bottle of wine says that the alcohol content is 11% (v/v). How many cm^3 of ethanol per litre does this wine contain?

2004 Question 10 (b)

Define *relative atomic mass*. (7)
Calculate the relative molecular mass of sulfuric acid (**H_2SO_4**) from the relative atomic masses of its elements. (6)
What is the percentage by mass of sulfur in sulfuric acid? (9)
How many moles of sulfuric acid are contained in 4.9 g of the acid? (3)

2005 Question 4 (h)

The label on a bottle of whiskey says that the alcohol content is 40% (v/v). How many cm^3 of ethanol are there in 30 cm^3 of the whiskey?

2006 Question 4 (i)

Calculate the percentage by mass of magnesium in magnesium sulfate (**$MgSO_4$**).

2007 Question 4 (g)

A 500 cm^3 sample of mineral water has a sodium content of 0.028 g.
Express the concentration of sodium in parts per million (ppm).

2008 Question 4 (i)

Calculate the percentage by mass of magnesium in magnesium sulfate (**$MgSO_4$**).

2009 Question 10(c)

(*i*) Define *relative atomic mass* (A_r). (7)
(*ii*) The molecular formula of glucose is **$C_6H_{12}O_6$** and its relative molecular mass is 180. What is the empirical formula for glucose? (6)
(*iii*) Calculate the percentage by mass of carbon in glucose. (6)
(*iv*) Another organic compound **B** has the same empirical formula as glucose but its relative molecular mass is 60. What is the molecular formula of **B**? (6)

Acids + Bases

2004 Question 10 (a)

(*a*) Define the terms (*i*) *acid*, (*ii*) *base* and (*iii*) *neutralisation*. (13)
Give an everyday example of neutralisation. (6)
Name a household base. (6)

2006 Question 7 (a)

(*a*) In 1884, the Swedish chemist, pictured on the right, proposed a new theory of acids and bases. He defined an acid as a substance which produces hydrogen ions (**H+**) by dissociation when dissolved in water.

(*i*) Identify the Swedish chemist. (5)
(*ii*) Define *base* according to the theory proposed by this chemist. (6)
(*iii*) Give **one** example of a common household acid and **one** example of a common household base. (6)
(*iv*) What do you understand by the term neutralisation? Give **one** everyday example. (9)

2008 Question 7 (a)

*(*a) In 1884, the Swedish chemist, Arrhenius, pictured on the right, proposed a new theory of acids and bases.

*(*i) How did Arrhenius define an acid? (5)
(*ii*) Give **one** example of a commonly used base and state **one** use made of it. (12)

2009 Question 4 (i)

The pH values of three solutions are 4, 9 and 6. Arrange these pH values in order of increasing acidity.

2009 Question 8(b)

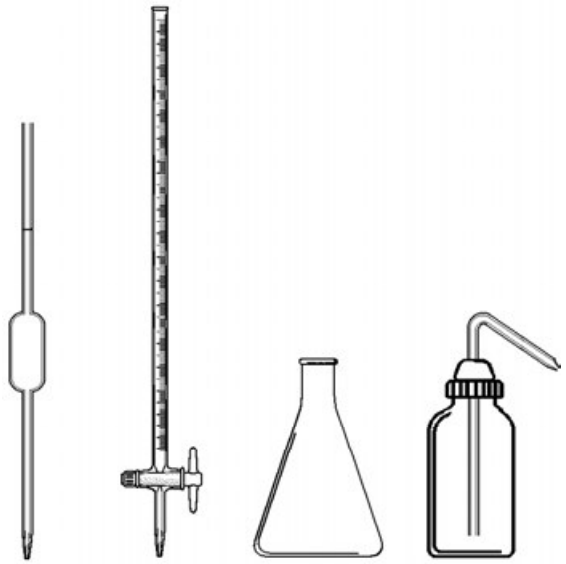
In the case of any **four** of the following, describe simple experiments, one in each case,
(*b*) to measure the pH of an aqueous solution,

Volumetric Analysis (Acid + Base)

2004 Question 2

A 0.10 M standard solution of sodium carbonate (**Na_2CO_3**) was used to find the concentration of a given hydrochloric acid solution by titration. The pieces of apparatus **A**, **B**, **C** and **D** shown in the diagram were used in the experiment.

(*a*) Name the pieces of apparatus **A**, **B**, and **C**. (11)
(*b*) Describe the correct procedure for rinsing **A** before using it to measure the sodium carbonate solution. (6)
(*c*) Mention **two** precautions which should be taken when using **B**. (9)
(*d*) **D** is a wash bottle containing deionised water. What use should be made of it *during* the titration? (6)
(*e*) Name a suitable indicator for this titration. What colour change was observed in **C** at the end point? (9)



A **B** **C** **D**

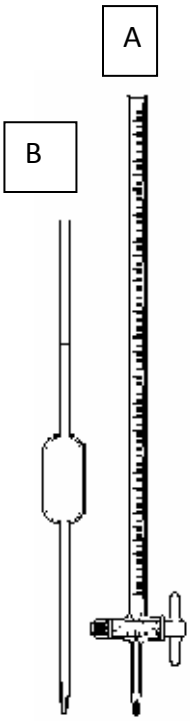
(*f*) The balanced equation for the titration reaction is:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

When the hydrochloric acid (**HCl**) solution was titrated a number of times against 25 cm^3 portions of the 0.10 M solution of sodium carbonate (**Na_2CO_3**) an average accurate titre of 20.0 cm^3 was obtained. Calculate the concentration of the hydrochloric acid solution in moles per litre. (9)

2005 Question 2

A 0.10 M standard solution of sodium hydroxide (**NaOH**) was used to find the concentration of a given hydrochloric acid (**HCl**) solution by titration. The pieces of equipment **A** and **B** shown in the diagram were used in the experiment.



(*a*) Name the pieces of equipment **A** and **B**. (8)

(*b*) Which of the two solutions is normally placed in the piece of equipment labelled **A**?
Describe the correct procedure for rinsing and filling **A**. (12)

(*c*) Name a suitable indicator for this titration.
What colour change was observed at the end point? (9)

(*d*) The balanced equation for the titration reaction is:

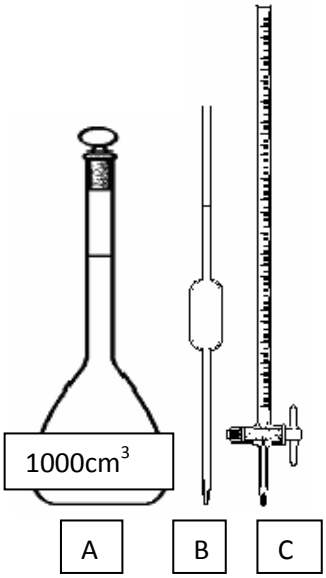
$$\mathbf{NaOH + HCl \rightarrow NaCl + H_2O}$$

When the hydrochloric acid (**HCl**) solution was titrated a number of times against 25 cm^3 portions of the 0.10 M solution of sodium hydroxide (**NaOH**), an average accurate titre of 22.6 cm^3 was obtained. Calculate the concentration of the hydrochloric acid solution in moles per litre. (9)

(*e*) Describe how this experiment could be used to prepare a pure sample of sodium chloride (common salt). (12)

2006 Question 2

A 0.06 M *standard solution* of sodium carbonate was made up by weighing out ***X*** grams of anhydrous sodium carbonate (**Na_2CO_3**), dissolving it in deionised water, and making the solution carefully up to the mark in a suitable 1 litre flask. This solution was then used to find, by titration, the concentration of a given hydrochloric acid (**HCl**) solution. Some of the pieces of equipment used are shown on the right.



(*a*) Name the piece of equipment **A** used to make up 1 litre of the **Na_2CO_3** solution. (5)

(*b*) What should be done with **A** and its contents immediately after bringing the solution up to the 1 litre mark with deionised water? Why is this important? (9)

(*c*) What is meant by a *standard solution*? (6)

(*d*) Calculate the mass (***X*** g) of sodium carbonate (**Na_2CO_3**) required to make 1 litre of a 0.06 M solution. (6)

(*e*) Name the pieces of equipment **B** and **C** used in the titration. (6)

(*f*) Name a suitable indicator for this titration and state the colour change at the end point. (6)

(*g*) What should be done with the conical flask and its contents *during the titration* in order to ensure an accurate result? (3)

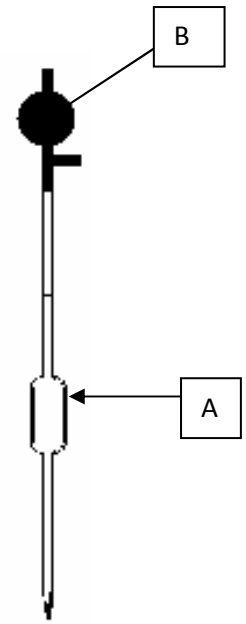
(*h*) A number of accurate titrations were carried out. It was found that, on average, 25.0 cm^3 of the 0.06 M sodium carbonate (**Na_2CO_3**) solution was neutralised by 30.0 cm^3 of the hydrochloric acid (**HCl**)

solution. Calculate the concentration of the hydrochloric acid solution in moles per litre. (9)
The balanced equation for the titration reaction is:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

2007 Question 2

A 0.10 M standard solution of hydrochloric acid (**HCl**) was used to find the concentration of a sodium hydroxide (**NaOH**) solution by titration. The piece of equipment **A** shown in the diagram was used in the experiment.



(*a*) Name the piece of equipment **A**. (5)
(*b*) (*i*) Which of the two solutions is usually measured using the piece of equipment labelled **A**?
(*ii*) Name the piece of equipment used to measure the second solution used in the titration. (12)

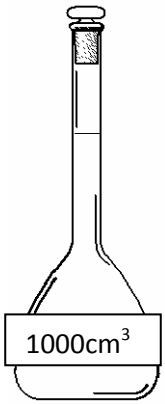
(*c*) (*i*) Describe the correct procedure for rinsing and filling **A**.
(*ii*) Why is it preferable to use a filler (labelled **B** in the diagram) rather than your mouth when filling **A**?
(*iii*) State **one** precaution you would take when transferring the liquid measured in **A** to the titration flask to ensure that the correct volume was transferred. (15)
(*d*) Name a suitable indicator for this titration.
What colour change was observed in the titration flask at the end point? (9)
(*e*) The balanced equation for the titration reaction is:

$$HCl + NaOH \rightarrow NaCl + H_2O$$

When the 0.10 M hydrochloric acid solution was titrated a number of times against 25.0 cm^3 portions of the sodium hydroxide solution an average accurate titre of 27.5 cm^3 was obtained.
Calculate the concentration of the sodium hydroxide solution in moles per litre. (9)

2008 Question 2

A standard (0.05 M) solution of sodium carbonate, **Na_2CO_3**, was made up in the flask shown in the diagram. After making up the solution, it was used to find the concentration of a hydrochloric acid, **HCl**, solution.



(*a*) What term is used to describe the type of flask shown in the diagram? (5)
(*b*) What is a *standard solution*? (6)
(*c*) Outline the steps involved in making up the standard solution of sodium carbonate. (12)
(*d*) In the titrations carried out to find the concentration of the hydrochloric acid solution, what piece of equipment is usually used to measure the volume of
(*i*) the sodium carbonate solution,
(*ii*) the hydrochloric acid solution? (12)

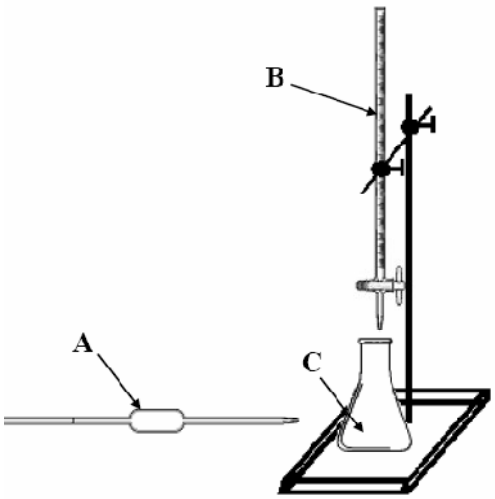
(*e*) Name an indicator suitable for a titration involving sodium carbonate and hydrochloric acid solutions. State the colour of the mixture at the end point. (6)
(*f*) It was found that 25.0 cm^3 of the 0.05 M sodium carbonate solution required 20.0 cm^3 of the hydrochloric acid solution for exact neutralisation. The balanced equation for the titration reaction is:

$$Na_2CO_3 + 2HCl \rightarrow 2NaCl + H_2O + CO_2$$

Calculate the molarity of the hydrochloric acid, **HCl**, solution. (9)

2009 Question 2

To prepare a pure sample of sodium chloride (common salt) in the school laboratory, the exact volume of a solution of hydrochloric acid (**HCl**), required to neutralise 25.0 cm^3 of a 0.10 M solution of sodium hydroxide (**NaOH**), was found by carrying out a number of titrations. The pieces of equipment used in carrying out these titrations are shown in the diagram on the right.



(*a*) Name the pieces of equipment **A**, **B** and **C**. (9)
(*b*) How would you have used **A** to measure 25.0 cm^3 of the sodium hydroxide solution and to transfer the solution into **C**? (9)
(*c*) Name a suitable indicator for the titration and state the colour change at the end point. (9)
(*d*) What is the correct procedure for reading the level of the hydrochloric acid solution in **B**? (6)
(*e*) If the exact volume of the hydrochloric acid solution required to neutralise 25.0 cm^3 of the 0.10 M solution of sodium hydroxide was 22.5 cm^3, calculate the molarity of the hydrochloric acid solution.
The equation for the reaction involved in the titrations is

$$HCl + NaOH \rightarrow NaCl + H_2O \quad (9)$$

(*f*) Describe the further steps needed to obtain a pure sample of sodium chloride. (8)

Oxidation and Reduction

2004 Question 11 (a)

(a) Define *oxidation* in terms of electron transfer. (7)

When zinc is added to copper sulfate solution the copper is displaced according to the equation:

$$\mathbf{Zn + CuSO_4 \rightarrow Cu + ZnSO_4}$$

(*i*) State **one** change observed as the reaction proceeds. (6)
(*ii*) Which substance is oxidised? (6)
(*iii*) Scrap iron can be used to extract copper metal. Which of these two metals is higher up the electrochemical series? (6)

2005 Question 4 (j)

Define *reduction* in terms of electron transfer.

2006 Question 4 (g)

Define *oxidation* in terms of electron transfer.

2007 Question 4 (i)

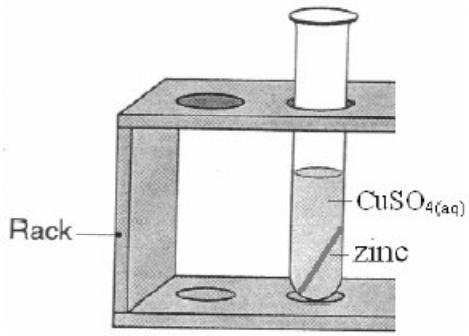
Define *oxidation* in terms of electron transfer.

2009 Question 11(a)

(*a*) Define *reduction* in terms of electron transfer. (4)
The diagram shows a piece of zinc in copper sulfate solution. Initially the zinc is silver-grey and the solution is blue. A reaction takes place which may be represented by the following equation.

$$\mathbf{Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu}$$

(*i*) Which species has been reduced?
How many electrons were transferred in the reduction? (6)
(*ii*) State any **two** changes you would observe as the reaction proceeds. (9)
(*iii*) Metals can be listed in the order of their ability to be oxidised. What is this list called? (6)



Volumetric Analysis (oxidation/reduction)

Rates of Reactions

2004 Question 7

Hydrogen peroxide solution decomposes rapidly in the presence of a manganese dioxide catalyst according to the following equation.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

In an experiment using this reaction, the oxygen gas was collected and its volume measured every minute until the reaction was complete. The data obtained is shown in the table.

Time/minutes	0	1	2	3	4	5	6	7	8
Volume of O_2/cm^3	0.0	7.7	11.7	14.8	17.2	19.0	19.8	20.0	20.0

(*a*) Draw a labelled diagram of the apparatus which could be used to carry out this reaction, collect the oxygen gas, and measure its volume. (11)
(*b*) On graph paper, plot a graph of the volume of oxygen gas produced (*y*-axis) against time (*x*-axis). (18)
(*c*) Was the rate of reaction faster after 1 minute or after 4 minutes? Explain your answer, referring to the shape of your graph in doing so. (6)
(*d*) Use the graph to estimate the volume of oxygen gas collected after 2.5 minutes. (9)
(*e*) Use the graph to estimate the time at which the reaction was complete. (6)

2005 Question 3

Hydrogen peroxide solution decomposes rapidly in the presence of a suitable catalyst according to the following equation.

$$2H_2O_2 \rightarrow 2H_2O + O_2$$

In an experiment using this reaction, the oxygen gas was collected and its volume measured every two minutes until the reaction was complete. The data obtained is shown in the table.

Time/minutes	0	2	4	6	8	10	12	14	16
Volume of O_2/cm^3	0.0	31	55	74	87	95	99	100	100

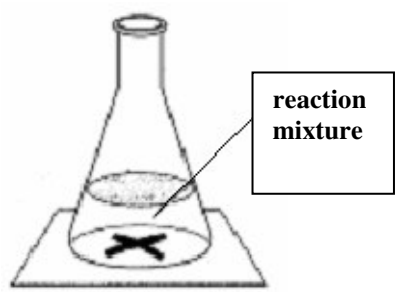
(*a*) What is a *catalyst*? Name a suitable catalyst for this reaction. (8)
(*b*) Draw a labelled diagram of an apparatus which could be used to carry out this reaction, collect the oxygen gas, and measure its volume. (12)
(*c*) On graph paper, plot a graph of the volume of oxygen gas produced (*y*-axis) against time (*x*-axis). (18)
(*d*) Why does the rate of oxygen production decrease as time passes? (6)
(*e*) Use the graph to estimate the volume of oxygen gas collected during the first 3 minutes. (6)

2006 Question 10 (c)

Catalysts are used in many important chemical processes. They are used, for example, in the catalytic converters in modern cars.
(*i*) Explain the term *catalyst*. (4)
(*ii*) Name **two** of the metals that form the catalyst in the catalytic converter of a car.
What is the advantage of using a catalytic converter? (12)
(*iii*) Name an element that poisons the catalyst present in a catalytic converter. (3)
(*iv*) Nitrogen monoxide (**NO**) and carbon monoxide (**CO**) react together in the catalytic converters of modern cars to give two gaseous products. Give the names or formulas of these products. (6)

2006 Question 11 (b)

Define *rate of reaction*. (7)
The effect of concentration on reaction rate can be studied using the reaction between sodium thiosulfate solution and hydrochloric acid. The apparatus shown in the diagram may be used. As the reaction proceeds, the reaction mixture becomes cloudy and, after a certain time, the cross becomes invisible when viewed through the solution. The equation for the reaction is



$$Na_2S_2O_3 + 2HCl \rightarrow 2NaCl + H_2O + SO_2 + S$$

(*i*) Which product of the reaction causes the reaction mixture to become cloudy? (6)
(*ii*) If a higher concentration of sodium thiosulfate solution were used in the reaction, would the time taken for the cross to become invisible be greater, less or unchanged? Explain your answer. (6)
(*iii*) If the conical flask were surrounded by ice-water, would the time taken for the cross to become invisible be greater, less or unchanged? Explain your answer. (6)

2007 Question 9

When a hydrogen peroxide (**H_2O_2**) solution was decomposed in the presence of a suitable catalyst, the oxygen gas produced was collected and its volume measured every three minutes until the reaction was complete. The data obtained is shown in the table.

Time/minutes	0	3	6	9	12	15	18	21
Volume of O_2/cm^3	0.0	30	45	53	57	59	60	60

(*a*) Give the name or formula of a suitable catalyst for this reaction. (5)
(*b*) Write a balanced equation for the decomposition of hydrogen peroxide (**H_2O_2**) to form oxygen gas (**O_2**) and water (**H_2O**). (6)
(*c*) Draw a labelled diagram of an apparatus that could be used to carry out this reaction, to collect the oxygen gas, and to measure its volume. (12)
(*d*) On graph paper, plot a graph of the volume of oxygen gas produced (*y*-axis) against time (*x*-axis). (18)
(*e*) Use your graph to estimate the volume of oxygen gas collected during the first 4.5 minutes. (6)
(*f*) When this reaction was repeated at a higher temperature it was found that the oxygen gas was produced more quickly. Why does this happen? (3)

2008 Question 10 (a)

(*a*) The table shows data obtained when a hydrogen peroxide solution decomposed to form water and oxygen in the presence of a catalyst.

Time Seconds	0	10	20	30	40	50	60	70
Volume of oxygen gas produced cm3	0	30	53	69	79	85	88	88

(*i*) On graph paper, plot the volume of oxygen produced (*y*-axis) against time (*x*-axis) (12)
(*ii*) Find from the graph the volume of oxygen produced in the first 15 seconds. (6)
(*iii*) Use the graph to find the time at which the reaction was finished. (7)

2008 Question 11 (b)

The catalytic converters found in modern cars contain certain metals spread over a fine honeycombed ceramic of very large surface area. Engine exhaust gases react on the surface of the hot solid catalyst to produce less-polluting tailpipe gases.

(*i*) Explain the term *catalyst*.
What term describes the type of catalysis described above? (7)
(*ii*) In the catalytic converter nitrogen monoxide (**NO**) and carbon monoxide (**CO**) react together to give two gaseous products. Identify these two products. (6)
(*iii*) Name **one** of the metals used as a catalyst in the catalytic converter of a car.
Name an element that poisons the catalysts present in a catalytic converter. (12)

2009 Question 3

The volume of oxygen released by hydrogen peroxide solution, in the presence of granular manganese(IV) oxide (**MnO_2**), was measured at one minute intervals until the reaction was complete.
The data obtained are shown in the following table.

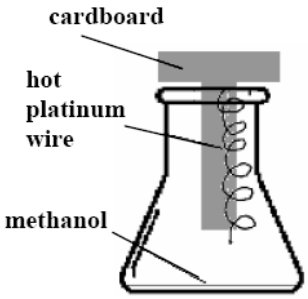
Time minutes	0	1	2	3	4	5	6	7
Volume cm^3	0	38	56	67	74	78	80	80

(*a*) What term is used to describe the function of the manganese(IV) oxide in this reaction? (5)
(*b*) Draw a diagram of a suitable apparatus for carrying out this experiment. (12)
(*c*) On graph paper, plot a graph of the volume of oxygen produced (*y*-axis) against time (*x*-axis). (15)
(*d*) Find from your graph the average rate of oxygen production in cm^3 per minute during the first three minutes of the reaction. (6)

(*e*) How would the reaction rate have been affected
(*i*) if the reaction had been carried out at a higher temperature,
(*ii*) if the granules of manganese(IV) oxide had been ground to a fine powder? (12)

2009 Question 4 (h)

The diagram on the right shows a hot platinum wire inserted in a heated flask over warm methanol. First the platinum wire glows, then there is a flash or flames and a popping sound and then all this repeats. What is the function of the hot platinum wire?



Chemical Equilibrium

2004 Question 4 (i)

Write the equilibrium constant expression (K_c) for the equilibrium

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

2005 Question 4 (i)

Write the equilibrium constant (K_c) expression for the equilibrium:

$$3H_2 + N_2 \rightleftharpoons 2NH_3$$

2006 Question 4 (h)

Write the equilibrium constant (K_c) expression for the equilibrium:

$$2SO_2 + O_2 \rightleftharpoons 2SO_3$$

2007 Question 4 (e)

Write the equilibrium constant (K_c) expression for the following reaction:

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)}$$

2008 Question 10 (c)

In the Haber process, nitrogen and hydrogen react to produce ammonia (**NH_3**).

$$N_{2\,(g)} + 3H_{2\,(g)} \rightleftharpoons 2NH_{3\,(g)} \qquad \Delta H = -92.4\ \text{kJ}$$

Le Châtelier's principle is applied in deciding the conditions required to give the best yield of the product.

(i) State *Le Châtelier's principle*. (7)

(*ii*) What does the symbol $\rightleftharpoons$ tell us about the reaction? (6)

(*iii*) Using Le Châtelier's principle, state whether you would use high or low temperature, and also whether you would use high or low pressure, in order to favour the production of ammonia in the Haber process. Give reasons for your choice of conditions. (12)

2009 Question 4 (j)

Write the equilibrium constant (K_c) expression for the following reaction.

$$H_2 + I_2 \rightleftharpoons 2HI$$

pH and Indicators

2004 Question 11 (b)

Define pH. (7)
Describe how you would use universal indicator paper (pH paper) or solution to measure the pH of a river water sample. (9)
Calculate the pH of a 0.001 M solution of nitric acid (**HNO_3**). (9)

2005 Question 10 (b)

*(*i) Define *pH*. (7)

The concentration of a solution of hydrochloric acid (**HCl**) is given as 3.65 grams per litre.

(*ii*) What is the concentration of the solution in moles per litre? (9)
(*iii*) Calculate the pH of the solution. (9)

2006 Question 7 (b)

(i) Define pH. (6)

The concentration of a solution of sodium hydroxide (**NaOH**) is as 4.0 grams per litre.
(*ii*) What is the concentration of the solution in moles per litre? (9)
(*iii*) Calculate the pH of the solution. (9)

2007 Question 10 (a)

(*i*) Define pH. (7)
(*ii*) Give **two** ways of measuring the pH of a solution. (6)
(*iii*) An aqueous solution has a pH of 7.5 at 25 ^{o}C. Is the solution acidic, basic or neutral? (3)
(*iv*) Calculate the pH of a 0.01 M solution of sodium hydroxide. (9)

2008 Question 7 (b)

*(*i) Define pH. (6)

(*ii*) Describe how you could measure the pH of a solution. (9)

The concentration of a solution of hydrochloric acid, **HCl**, is 3.65 grams per litre.

(*iii*) What is the concentration of the solution in moles per litre? (9)

(*iv*) Calculate the pH of the solution. (9)

Environmental Chemistry (Water)

2004 Question 4 (h) + (j)

A 100 cm^3 sample of sea water contained 0.022 grams of suspended solids. Calculate the concentration of suspended solids in p.p.m.

Why is chlorine added to domestic water supplies?

2004 Question 9

(*a*) What is meant by the term *hard water*? (5)
How may *temporary* hardness be removed from a water sample? (6)
Give the name **and** formula of a compound which causes *permanent* hardness in water (9)
(*b*) Select from the following list the answers to the questions labelled (*i*) to (*v*) below.

eutrophication **bacterial breakdown**
phosphates and nitrates **settlement and screening** **silage effluent**

(*i*) What takes place in the primary treatment of sewage?
(*ii*) What process occurs in the secondary treatment of sewage?
(*iii*) What does tertiary treatment of sewage remove?
(*iv*) Which term describes the enrichment of water with nutrients?
(*v*) Name a pollutant which can cause the enrichment of water with nutrients. (30)

2005 Question 4 (f)

A 500 cm^3 bottle of mineral water contains 0.480 g of dissolved solids. Calculate the concentration of dissolved solids in p.p.m.

2005 Question 9

(a) The following words all refer to stages in water treatment. These words are omitted from the Passage below:

chlorination **filtration** **flocculation**

pH adjustment **fluoridation** **sedimentation**

Write in your answer book the omitted words corresponding to each of the numbers 1 to 6. (36)

Aluminium sulfate and/or a polyelectrolyte is added to water to help suspended solids clump together in a process called _____1_____. Following this addition the suspended solids are allowed settle to the bottom of _____2_____ tanks. Bacteria in the water are destroyed by _____3_____. Lime or acid is added to carry out _____4_____. In Ireland _____5_____ of water is carried out in urban supplies to help prevent tooth decay. The water is passed through beds of sand and gravel to remove any remaining suspended solids in a process called _____6_____.

(*b*) Identify **two** substances removed by the tertiary treatment of sewage effluent.
State **one** damaging environmental effect of these substances. (14)

2005 Question 10 (c)

It is possible to estimate the *free chlorine* in swimming pool water or bleach using a colorimeter or a comparator.
(*i*) Describe how you could measure the free chlorine in either swimming pool water or bleach using one of these methods. (18)
(*ii*) Outline briefly the principles on which the technique you have described in (*i*) is based. (7)

2006 Question 3

A student was given a bucket of sea water for analysis. The student was asked to find out the concentrations of suspended and dissolved solids in the sea water. The student was also asked to carry out tests to show that the sea water contained sodium ions and chloride ions.

(*a*) To measure the amount of suspended solids present, the student filtered 500 cm^3 of the sea water through a weighed clean dry filter paper. The student then washed the filter paper through with a little distilled water, dried it, and reweighed the filter paper. The filter paper had increased in mass by 0.44 g.
(*i*) Why did the student wash the filter paper with distilled water after filtering the sea water? (8)
(*ii*) Express the concentration of suspended solids in p.p.m. (6)

(*b*) Describe how the student could have then measured the concentration of dissolved solids in the sea water. (12)

(*c*) Describe how the student could have carried out a flame test to show that a sodium salt was present in the dissolved solids collected. What flame colour would indicate the presence of sodium ions? (18)

(*d*) How could the student have tested the sea water to show that chloride ions were present? (6)

2006 Question 9

(*a*) The treatment of drinking water for an urban supply consists of a number of stages.
In the case of **any three** of the stages in the treatment process, state the treatment involved and why it is carried out. (20)

(*b*) The following words all relate to sewage treatment. These words are omitted from the passage below:

eutrophication **nitrates** **biological** **sedimentation** **solid**

Write in your answer book the omitted words corresponding to each of the numbers 1 to 5. (30)

In primary treatment, sewage is passed through grids and over grit channels to remove dense

_____**1**_____ material. The sewage is then transferred to _____**2**_____ tanks where suspended solids

are allowed settle to the bottom. In secondary treatment the sewage is broken down by **_____3_____** digestion. Tertiary treatment removes phosphates and **_____4_____**. These nutrients can cause **_____5_____** if their concentrations build up in lakes and rivers.

2007 Question 4 (f)

Distinguish between *temporary* and *permanent* hardness of water.

2007 Question 10 (c)

The following procedures are involved in the treatment of water for domestic use.

flocculation **filtration** **pH adjustment** **fluoridation**

(*i*) What is meant by flocculation? What substance is added to the water to bring it about? (7)
(*ii*) Outline briefly how the filtration of the water is carried out. What is removed from the water by this procedure? (9)
(*iii*) If the pH of the water were found to be too low, what substance could be added in order to raise it? (3)
(*iv*) How is fluoridation of the water brought about? What is the purpose of fluoridation? (6)

2007 Question 11 (b)

The treatment of sewage can be broken into three stages: **primary**, **secondary** and **tertiary**.

(*i*) Which stage involves the biological breakdown of organic matter present in the sewage? (6)
(*ii*) Which stage involves the screening and settling of the sewage to remove large particles? (6)
(*iii*) Which stage involves the reduction of the levels of nitrates and phosphates? (6)
(*iv*) Why is it important to reduce the levels of nitrates and phosphates in sewage effluent? (7)

2008 Question 8

(a) The treatment of water for domestic use may involve each of the following stages.

Sedimentation **flocculation** **filtration** **chlorination**

fluoridation **pH adjustment**

State the purpose of **four** of these stages and describe how the water is treated in each of the four stages you have chosen. (24)
(*b*) The treatment of domestic and industrial effluent is normally divided into three stages: **primary**, **secondary** and **tertiary**.
Explain what happens in each of these stages. (18)

(*c*) Give **two** environmental consequences of discharging untreated sewage into a river. (8)

2009 Question 4 (c)

State the function of (*i*) chlorination, (*ii*) fluoridation, in water treatment.

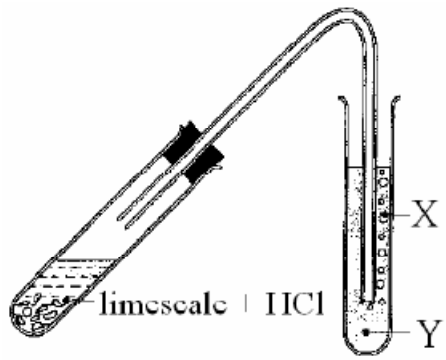
2009 Question 9

(*a*) What is meant by *hardness* in water? (5)
The following names/terms all relate to hardness in water.

calcium sulfate **temporary** **permanent** **ion exchange** **calcium hydrogencarbonate**

Write in your answer book the name/term corresponding to each of the numbers 1 to 5 in the statements below.

Dissolved __**1**__ causes __**2**___ hardness which is removed when water is boiled.
Dissolved ___**3**___ causes ___**4**___ hardness which is *not* removed when water is boiled.
Both forms of hardness are removed by ___**5**___ . (15)



The diagram shows a test tube containing limescale (scraped from the inside
of a kettle) and dilute hydrochloric acid (**HCl**). As the gas **X** produced by the reaction is bubbled through solution **Y**, the solution becomes milky (cloudy). Identify the gas **X** and liquid **Y**. (6)

(*b*) In an experiment to measure the concentration of suspended solids in a water sample, a volume of 200 cm^3 of the water was found to contain 0.02 g of suspended solids.
Find the concentration of suspended solids in parts per million (ppm). (12)
Outline how the mass of suspended solids was obtained in the experiment.(12)

Electrochemistry

2005 Question 11 (b)

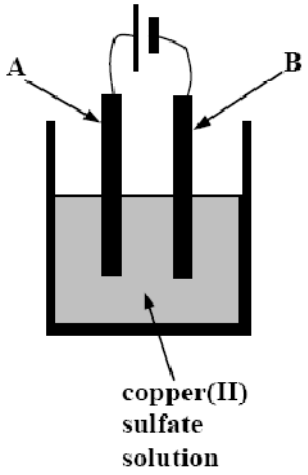
The diagram shows an arrangement for the electrolysis of copper(II) sulfate solution using copper electrodes.

(*i*) Write the chemical formula for copper(II) sulfate.
What colour is the copper(II) sulfate solution? (7)

(*ii*) State **one** change which happens to the electrode labelled **A** during the experiment. (6)

(*iii*) If you wished to electroplate a metal object with copper, which of the electrodes, **A** or **B**, should be replaced by the object? (6)

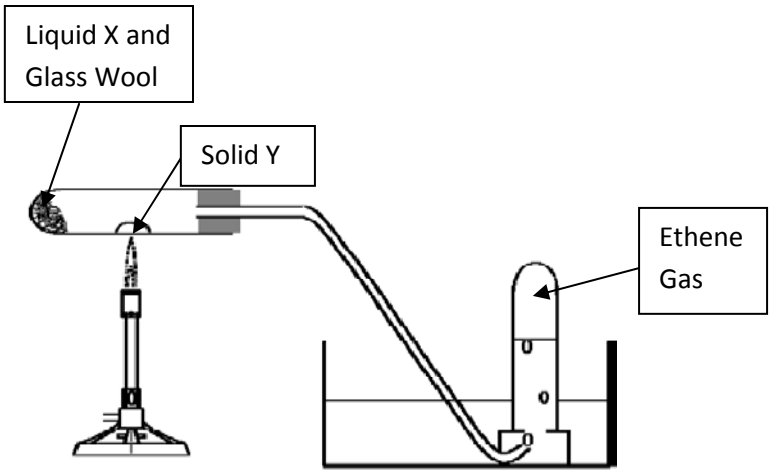
(*iv*) If you wished to purify a sample of copper, which of the electrodes, **A** or **B**, should you replace with the piece of impure copper? (6)



Fuels and Heats of Reaction

2004 Question 1

The apparatus shown in the diagram was used to prepare a sample of ethene gas (**C_2H_4**). A little of liquid **X** was poured into a boiling tube and some glass wool was pushed to the end of the boiling tube. Some powdered solid **Y** was heaped about halfway along the tube. A Bunsen flame was used to heat the outside of the boiling tube under **Y**. A number of test tubes of gas were collected.



(*a*) Identify the liquid **X** and the solid **Y**. (8)
What is the colour of solid **Y**? (3)

(*b*) What is the purpose of the glass wool? (6)

(*c*) Why were the first few test tubes of gas collected not used? (6)

(*d*) When heating is stopped at the end of the experiment a suck back of water into the boiling tube is likely to occur. Why might a suck back occur when the heating is stopped, and what action should be taken to avoid this happening? (9)

(*e*) Describe a laboratory test you could carry out on a test tube of ethene to show combustion of the gas.

What is observed during this test? What are the products of the combustion reaction?
Describe a test to confirm the presence of **one** of these combustion products. (18)

2004 Question 3

The diagram shows an apparatus used to measure the heat of reaction (Δ***H***) for the reaction between hydrochloric acid (**HCl**) and a solution of sodium hydroxide (**NaOH**).

(*a*) The reaction occurring in this experiment is *exothermic*. Explain the term *exothermic*. (5)

(*b*) Name a suitable material for container **M**.
Explain your choice of material. (12)

(*c*) Name a piece of apparatus which could have been used in this experiment to measure out 100 cm^3 of hydrochloric acid solution accurately. (3)

(*d*) State **one** precaution which could have been taken to obtain an accurate value for the final temperature reached when the two solutions were mixed. (6)

(*e*) Both hydrochloric acid and sodium hydroxide solutions are corrosive.
Describe or draw a clear diagram of the hazard-warning symbol that should be used on the labels of bottles to indicate that the contents are corrosive. (6)

(*f*) When 100 cm^3 of 1.0 M hydrochloric acid reacted with excess sodium hydroxide solution, 5.71 kJ of heat were produced.
(*i*) How many moles of hydrochloric acid reacted?
(*ii*) How many kJ of heat would have been produced if one mole of hydrochloric acid (**HCl**) reacted?
(*iii*) Hydrochloric acid reacts with sodium hydroxide according to the equation:

$$\mathbf{HCl + NaOH \rightarrow NaCl + H_2O}$$

What is the heat of reaction ($\Delta \boldsymbol{H}$) for the reaction between hydrochloric acid and sodium hydroxide? (12)

(*g*) The energy content (calorific value) of foods and fuels can be measured in a special piece of apparatus. Name this apparatus. (6)

2004 Question 6

The following compounds are all used as fuels:

Methane **butane** **benzene** **ethyne** **hydrogen**

(a) Select from the list above one compound in each case which
(*i*) is often formed in refuse dumps and slurry pits, (5)
(*ii*) is used in oxyacetylene torches for cutting and welding, (6)
(*iii*) is used as a fuel for space rockets, (6)
(*iv*) is a component of liquid petroleum gas (LPG), (6)
(*v*) has a high octane number. (6)

(*b*) One of the compounds listed above is described as *aromatic*. Which compound is *aromatic*? Draw a diagram to show the structure of a molecule of this compound. (12)

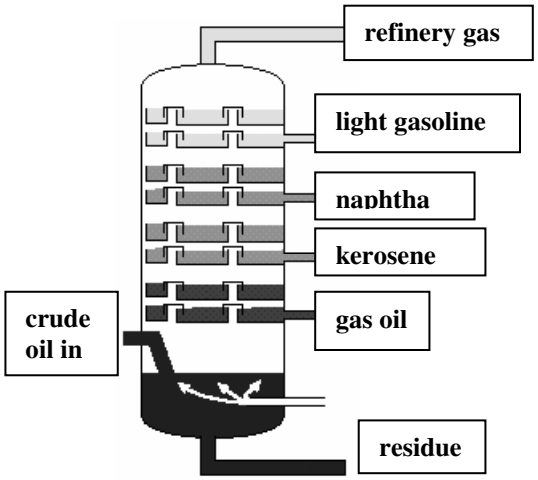
(*c*) Give **one** disadvantage of hydrogen as a fuel. (3)
State **one** method of manufacturing hydrogen gas on an industrial scale. (6)

2005 Question 4 (c)

Name the piece of equipment used to measure the calorific value of foods and fuels.

2005 Question 10 (a)

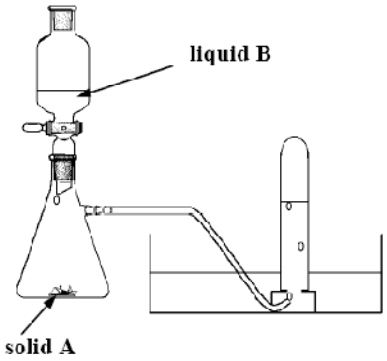
(*a*) The diagram shows a fractionation tower of an oil refinery. The main fractions produced are named.
(*i*) Which fraction is used as tar or bitumen in surfacing roads? (7)
(*ii*) Identify the fraction which is rich in propane and butane, and which is used as a fuel for outdoor (space) heaters? (6)
(*iii*) Which fraction is used as an aircraft fuel? (6)



(*iv*) Which fraction is a heavy fuel oil used in furnaces? (6)

2005 Question 6

(*a*) Alkynes form a *homologous series* of which ethyne (**C_2H_2**) is the first member.
(*i*) What is a *homologous series*? (5)
(*ii*) Draw the structure of the ethyne molecule. (6)
(*iii*) In a chemical reaction, three molecules of ethyne can combine to form an aromatic molecule of formula **C_6H_6**. Give the name *or* structure of this molecule. (6)
(*b*) The diagram on the right shows an apparatus which could be used for the preparation of ethyne gas.
(*i*) Identify the solid **A** and the liquid **B** used in the preparation. (12)
(*ii*) Describe what you would observe when a sample of ethyne gas is burned in air. (6)
(*iii*) Describe a test you could carry out on a sample of ethyne gas to show that the gas is unsaturated. (9)
(*iv*) Give **one** major use of ethyne gas. (6)

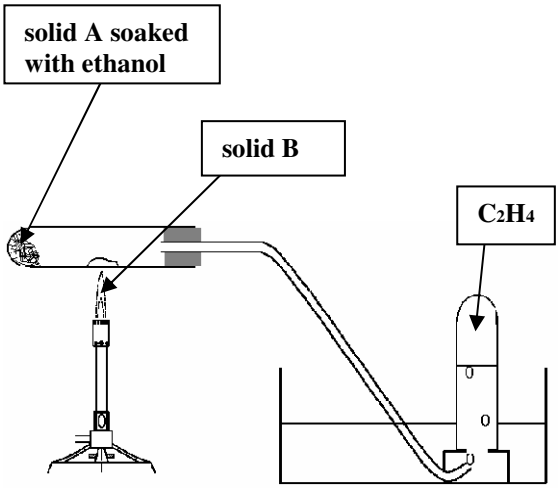


2006 Question 1

Ethene (**C_2H_4**) and ethyne (**C_2H_2**) are *unsaturated* hydrocarbons. They can both be easily prepared in a school laboratory.

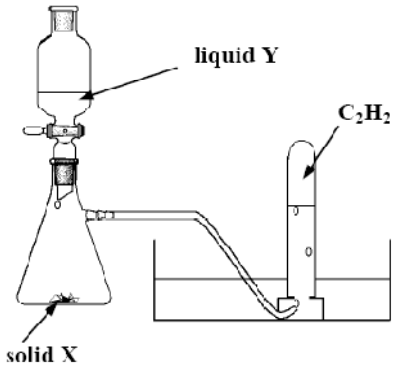
(*a*) The diagram on the right shows an apparatus which could be used for the preparation of ethene gas (**C_2H_4**).

(*i*) Identify solid **A** which is used to keep the ethanol at the end of the test tube. (5)
(*ii*) Give the name or formula of solid **B** which is heated using the Bunsen burner. (6)
(*iii*) What precaution should be taken when heating is stopped? Why is this necessary? (6)
(*iv*) Give **one** major use of ethene gas. (3)



(*b*) The diagram on the right shows an apparatus which could be used for the preparation of ethyne gas (**C_2H_2**).

(*i*) Identify solid **X** and liquid **Y**, the reagents used in the preparation. (12)
(*ii*) Describe what you would observe when a sample of ethyne gas is burned in air. (6)
(*iii*) Give **one** major use of ethyne gas. (3)



(*c*) Describe a test you could carry out on either of the two gases to show that it is *unsaturated*. What would you observe during the test? (9)

2006 Question 4 (b) + (d) + (e)

What is an *endothermic reaction*?

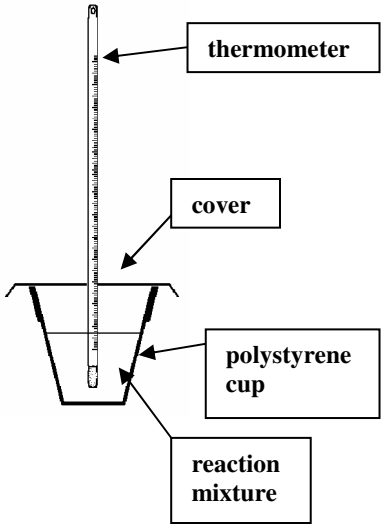
Name the piece of equipment used to measure the calorific values of foods and fuels.

Methylbenzene (toluene) is an aromatic compound of molecular formula $\mathbf{C_7H_8}$.
Give its structural formula. State **one** common use of methylbenzene.

2006 Question 6 (a) + (b)

(a) Hydrocarbons are widely used as fuels.
(*i*) What are *hydrocarbons*? Give **one** major source of hydrocarbons. (8)
(*ii*) Increasing levels of methane ($\mathbf{CH_4}$) in the lower atmosphere are a concern to environmentalists at present. Explain why this is so. (6)
(*b*) Liquid petroleum gas (LPG) is used as a fuel in patio heaters.
A major component of LPG includes hydrocarbons of molecular formula $\mathbf{C_4H_{10}}$. Draw the structure and give the systematic (IUPAC) name of each of the **two** structural isomers of $\mathbf{C_4H_{10}}$. (12)

2007 Question 3



The apparatus drawn was used in a student experiment to measure the heat of reaction (**ΔH**) for the reaction between 1.0 M hydrochloric acid (**HCl)** solution and 1.0 M sodium hydroxide (**NaOH**) solution. When 50 cm^3 of the hydrochloric acid solution was added to 50 cm^3 of the sodium hydroxide solution in the polystyrene cup it was found that 2.8 kJ of heat energy was produced by the reaction. The equation for the reaction is:

$$\mathbf{HCl + NaOH \rightarrow NaCl + H_2O}$$

(*a*) What is meant by *heat of reaction*? (5)
(*b*) How do the temperature measurements taken during the experiment provide evidence that the
reaction between **HCl** and **NaOH** is exothermic? (6)
(*c*) What is the advantage of using a cup made from polystyrene? (6)
(*d*) How would you have obtained a reasonably accurate value for the change in temperature? (9)
(*e*) Calculate (*i*) the number of moles of hydrochloric acid (**HCl**) in 50 cm^3 of 1.0 M hydrochloric acid,
(*ii*) the heat in kJ which would be produced if a solution containing 1 mole of hydrochloric acid reacted fully with sodium hydroxide,
(*iii*) the heat of reaction (**Δ*H***) for the reaction. (18)
(*f*) What term is used for the reaction between an acid and a base resulting in the production of a salt and water? (6)

2007 Question 4 (c) + (d)

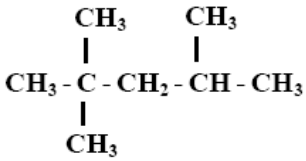
Give **one** industrial source of hydrogen gas.

Name the piece of equipment used to measure the calorific values of foods.

2007 Question 6

The engines in many modern cars perform well using petrol with an octane number of 95.

A



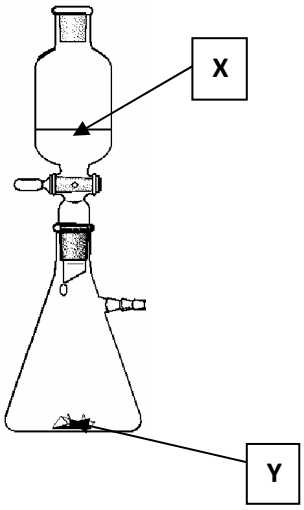
B

(*a*) What do you understand by *octane number*? (8)
(*b*) The structures of the two compounds (**A** and **B**) on which octane numbers are based are shown on the right. Name the **two** compounds. (12)
(*c*) One of these two compounds is assigned an octane number of 100, and the other an octane number of 0. Which compound is assigned the higher octane number? (6)
(*d*) Suggest **one** conversion that could be carried out in an oil refinery on the compound of zero octane number in order to produce a compound of higher octane number. (6)
(*e*) The molecular formula for benzene is **C_6H_6**. Draw the structure of the molecule. Would you expect the octane number of benzene to be high or low? Give a reason for your answer. (12)
(*f*) What effects would be noticed when driving a car if the octane number of the petrol used were too low?(6)

2007 Question 8 (a), (b) + (c)

Answer the questions below with reference to the compounds **A**, **B** and **C**.

C_2H_2	C_2H_4	C_2H_5Cl
A	**B**	**C**



(*a*) Which one of the three compounds is not a hydrocarbon? (5)
(*b*) Give the systematic (IUPAC) names of **A**, **B**, and **C**. (9)
(*c*) Compound **A** can be prepared in the school laboratory by dropping liquid **X** onto solid **Y** using the apparatus shown in the diagram.
(*i*) Identify **X** *and* **Y**.
(*ii*) Explain, by means of a diagram, how **A** may be collected.
(*iii*) Describe how would you show that **A** is unsaturated? (24)

2008 Question 4 (b)

What is an *endothermic reaction*?

2007 Question 4 (d) + (e)

Name the piece of equipment used to measure the calorific values of foods and fuels.

What is meant by the *octane number* of a fuel?

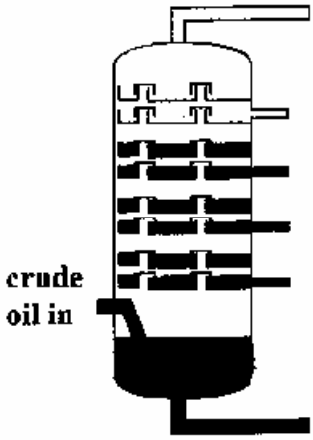
2008 Question 6

Hydrogen gas and the hydrocarbons ethyne and butane are all used as fuels.

(a) What are (*i*) *hydrocarbons*, (*ii*) *fuels*? (8)

(*b*) (*i*) Which of the three fuels, named above, is a major component of liquid petroleum gas (LPG) used as a fuel in patio heaters?
(*ii*) Which of the three fuels is used as a fuel for space rockets?
(*iii*) Which of the three fuels has the common name acetylene and is used in high temperature cutting equipment? (15)

(*c*) Write structural formulas for the hydrocarbons ethyne and butane. (12)

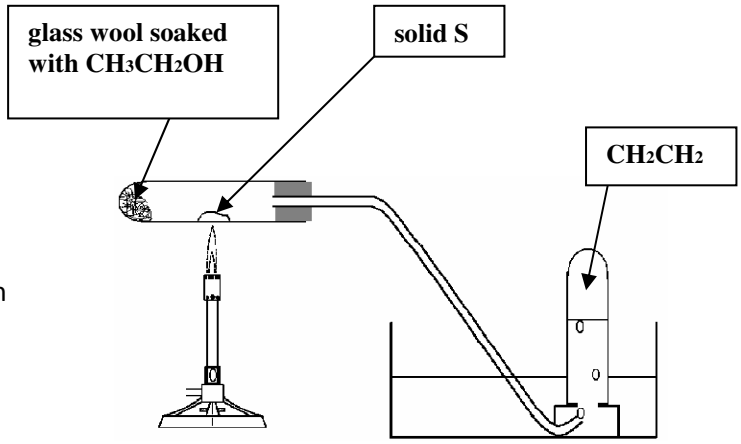


(*d*) The diagram on the right shows a fractionating column used in oil refining. Crude oil is separated into fractions that come off through the outlet pipes on the right-hand side of the column.
Name **one** of the fractions obtained by the fractionating process.
State whether this fraction is collected from high up, from the middle or from low down the fractioning column.
State **one** major use of this fraction. (15)

2008 Question 9 (d)

$$\underset{X}{CH_2CH_2} \longleftarrow \underset{Y}{CH_3CH_2OH} \longleftarrow \underset{Z}{CH_3CHO}$$

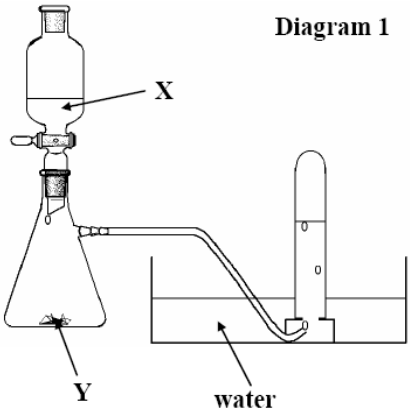
An apparatus suitable for the conversion of **Y** to **X** in a school laboratory is drawn on the right.



(*i*) Give the name or formula of the white solid **S**.
(*ii*) Why should the delivery tube be removed from the trough of water when the heating is stopped?
(*iii*) Describe one test you carried out on **CH_2CH_2**.
State the observation you made and the conclusion drawn. (24)

2009 Question 1

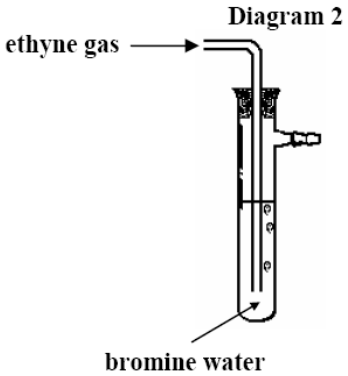
Diagram 1 shows an apparatus used for the preparation and collection of ethyne gas (**C_2H_2**).



(a) Name the homologous series to which ethyne belongs. (5)

(*b*) Identify the liquid **X** and the solid **Y**.
Describe the appearance of the solid **Y**. (15)

(*c*) Diagram 2 shows ethyne gas being bubbled through bromine water in a test tube.
What change would you expect to observe in the appearance of the bromine water?
What explanation would you give for this observation? (12)



(*d*) What is observed when a sample of ethyne gas is burned in air? (6)

(*e*) When ethyne gas (commonly known as acetylene) is mixed with another gas in suitable proportions,
the mixture burns with a very hot flame.
Identify the gas that is mixed with ethyne.
What use is made of the very hot flame? (12)

2009 Question 4 (f) + (g)

Balance the combustion equation: $C_3H_8 + O_2 \longrightarrow CO_2 + H_2O$

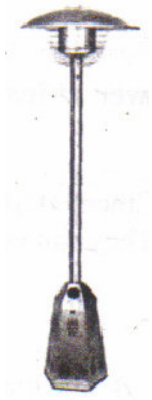
What term describes a chemical reaction for which the value of **Δ*H*** is negative?

2009 Question 6

(*a*) Explain what is meant by *fractionation* in the oil refining process. (5)
Select any **two** of the fractions below and state **one** common use of each of the chosen fractions. (12)

light gasoline naphtha kerosene gas oil

(*b*) LPG is obtained from a gaseous fraction (refinery gas). LPG consists mainly of propane (**C_3H_8**) and butane (**C_4H_{10}**) with small amounts of mercaptans added.
LPG is widely used in gas-burning appliances e.g. domestic gas cookers and patio heaters. The diagram on the right shows a common type of patio heater.



(*i*) What do the letters LPG stand for? (6)
(*ii*) Draw the structure of **one** of the two isomeric forms of **C_4H_{10}**. (6)
(*iii*) Why are mercaptans added to LPG? (6)
(*iv*) Why is the use of patio heaters being discouraged by environmentalists? (6)
(*c*) Give **one** advantage and **one** disadvantage of using hydrogen as a fuel.
State **one** industrial use of hydrogen other than its use as a fuel. (9)

Families of Organic Compounds

2004 Question 4 (f)

Write the name or formula of the carboxylic acid found in vinegar.

2004 Question 8

Examine the reaction scheme and answer the questions that follow:

$$\underset{A}{CH_2CH_2} \xrightarrow{X} \underset{B}{CH_3CH_3} \xrightarrow{Y} \underset{C}{CH_3CH_2Cl}$$

(*a*) Which **one** of the compounds **A**, **B** or **C** is an unsaturated hydrocarbon? (5)
(*b*) Which **one** of the compounds **A**, **B** or **C** has only planar carbon atoms? (6)
(*c*) Name the compounds **A**, **B** and **C**. (18)

2005 Question 4 (d)

Give the name or formula of the acid which is the cause of the sting of nettles.

2006 Question 8 (a), (b) + (c)

Answer the questions below with reference to compounds **X**, **Y** and **Z** in the following reaction scheme.

$$\underset{X}{CH_3CH_2OH} \longrightarrow \underset{Y}{CH_3CHO} \longrightarrow \underset{Z}{CH_3COOH}$$

(*a*) Which **one** of the compounds **X**, **Y** or **Z** has only tetrahedrally bonded carbon atoms? (5)
(*b*) Give the names of the compounds **X**, **Y** and **Z**. (9)
(*c*) Which of the three compounds **X**, **Y** or **Z** is found
(*i*) in concentrations of about 6 – 15% (v/v) in wine,
(*ii*) in concentrations of about 6% (v/v) in vinegar? (12)

2008 Question 9 (a),(b) + (c)

Answer the questions below with reference to compounds **X**, **Y** and **Z** in the following reaction scheme.

$$\underset{X}{CH_2CH_2} \longleftarrow \underset{Y}{CH_3CH_2OH} \longleftarrow \underset{Z}{CH_3CHO}$$

(*a*) Which **one** of the compounds **X**, **Y** or **Z** has only planar bonded carbon atoms? (5)
(*b*) Give the names of the compounds **X**, **Y** and **Z**. (9)
(*c*) Which of the three compounds **X**, **Y** or **Z**
(*i*) is found in concentrations of about 40-55% (v/v) in whiskey,
(*ii*) is used to make the plastic poly(ethene) [polythene]? (12)

2009 Question 7

Answer the questions below with reference to the organic compounds **A**, **B**, **C** and **D**.

CH_2CH_2	CH_3CH_2OH	CH_3COOH	C_6H_6
A	**B**	**C**	**D**

(*a*) Which **one** of the compounds **A**, **B**, **C** or **D** has no planar carbon atom? (8)

(*b*) Name the compounds **A**, **B**, **C** and **D**. (12)

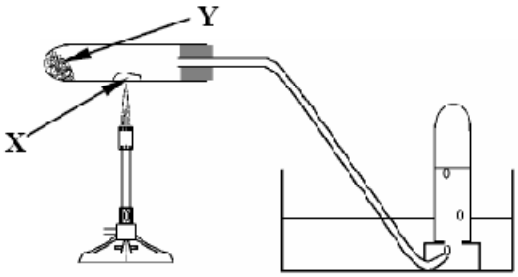
(*c*) What type of reaction is involved in the conversion of **B** to **C**?
Name the common flavouring agent that consists of a 6% (v/v) solution of **C**. (6)

(*d*) The conversion of **B** to **A** is carried out in the school laboratory using the apparatus shown on the right.

(*i*) Identify the substance **X**.
Describe the appearance of this substance.

(*ii*) How is compound **B** held at position **Y** in the test tube?

(*iii*) Why should the delivery tube be removed from the trough of water before heating is stopped? (15)



(*e*) The usual representation of the structure of compound **D** is shown in the diagram on the right.

What term is used for organic compounds that contain this structure?
What serious health hazard is associated with compound **D**? (9)

Types of Reaction in Organic Chemistry

2004 Question 8

Examine the reaction scheme and answer the questions that follow:

$$\underset{A}{CH_2CH_2} \xrightarrow{X} \underset{B}{CH_3CH_3} \xrightarrow{Y} \underset{C}{CH_3CH_2Cl}$$

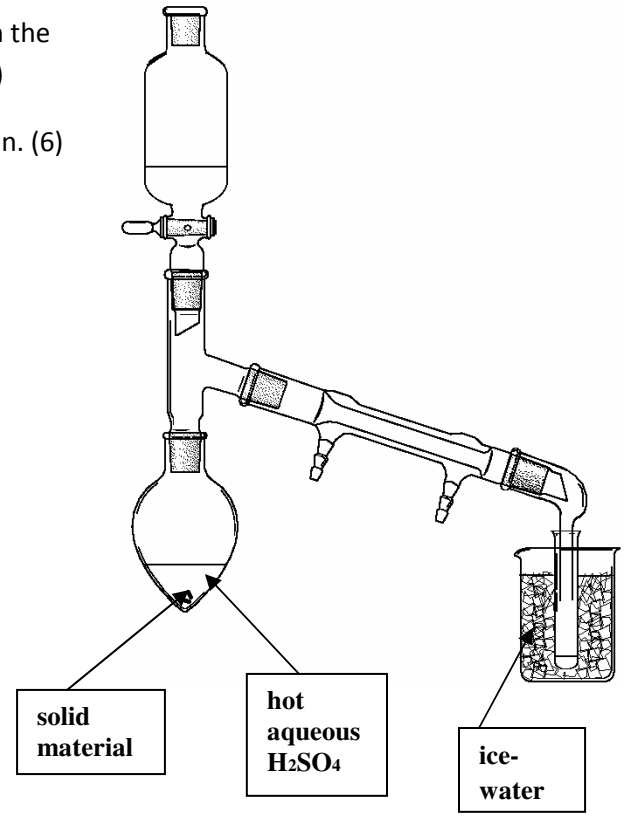
(*a*) Which **one** of the compounds **A**, **B** or **C** is an unsaturated hydrocarbon? (5)
(*b*) Which **one** of the compounds **A**, **B** or **C** has only planar carbon atoms? (6)
(*c*) Name the compounds **A**, **B** and **C**. (18)
(*d*) Classify (*i*) conversion **X** and (*ii*) conversion **Y** as an *addition*, *elimination* or *substitution* reaction. (12)
(*e*) Which **one** of the compounds **A**, **B** or **C** is easily polymerised?
State the name of the polymer formed. (9)

2005 Question 1

A group of students prepared ethanal (**CH_3CHO**) by slowly adding a mixture of ethanol (**C_2H_5OH**) and an oxidising agent in water, to hot aqueous sulfuric acid. The apparatus drawn below was used.

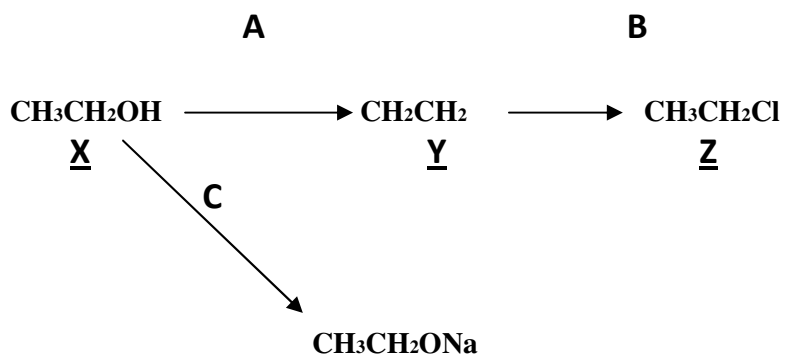
(a) At the start of the experiment a few pieces of a solid material were placed in the reaction flask along with the sulfuric acid. Identify this solid and state its purpose. (8)

(*b*) Identify a suitable oxidising agent for this preparation. (6)
(*c*) What is the colour of the mixture in the dropping funnel at the start? (6)
(*d*) What is the colour of the mixture in the reaction flask as the reaction proceeds? (6)
(*e*) Why is it important to distill off the ethanal as it is produced? (6)
(*f*) Why is it not necessary to keep heating the reaction flask during the addition? (6)
(*g*) Why is the receiving vessel cooled in ice-water? (6)
(*h*) What colour is the solid produced when a mixture containing a few drops of Fehling's solutions (No 1 and No 2) and ethanal is heated? (6)



2005 Question 8

Examine the reaction scheme and answer the questions that follow:



(*a*) Which **one** of the compounds **X**, **Y** or **Z** is an unsaturated hydrocarbon? (5)
(*b*) Name the compound **Y**. (6)
(*c*) Classify (*i*) conversion **A**, (*ii*) conversion **B**, as an *addition*, an *elimination* or a *substitution* reaction. (12)
(*d*) Draw a clearly labelled diagram of the apparatus used to carry out conversion **A** in a school laboratory.
Identify the compound used to bring about this conversion. (15)
(*e*) What reagent is used to bring about (*i*) conversion **B**, (*ii*) conversion **C**? (12)

2005 Question 11 (a)

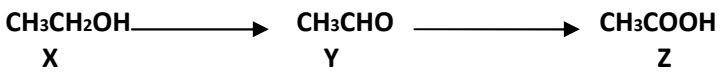
Paper chromatography, thin-layer chromatography and column chromatography are all separation techniques.
(*i*) Describe with the aid of a diagram an experiment to separate a mixture of indicators using **one** of these techniques. (15)
(*ii*) What material is the stationary phase in the experiment you have described? (5)
(*iii*) Give **one** example of the use of thin-layer chromatography in forensic science. (5)

2006 Question 4 (j)

Identify **one** natural product that is extracted by steam distillation.

2006 Question 8

Answer the questions below with reference to compounds **X**, **Y** and **Z** in the following reaction scheme.



(*a*) Which **one** of the compounds **X**, **Y** or **Z** has only tetrahedrally bonded carbon atoms? (5)
(*b*) Give the names of the compounds **X**, **Y** and **Z**. (9)

(*c*) Which of the three compounds **X**, **Y** or **Z** is found
(*i*) in concentrations of about 6 – 15% (v/v) in wine,
(*ii*) in concentrations of about 6% (v/v) in vinegar? (12)
(*d*) Both conversions (**X** to **Y** and **Y** to **Z**) are of the same reaction type.
(*i*) What term is used to describe this type of reaction?
(*ii*) What reagents could be used to bring about both of these conversions? (18)
(*e*) What observation is made when a sample of compound **Y** is heated with Fehling's reagent? (6)

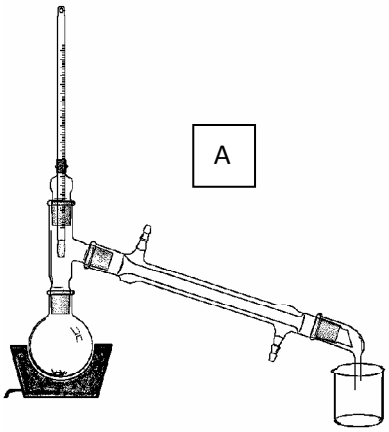
2006 Question 10 (b)

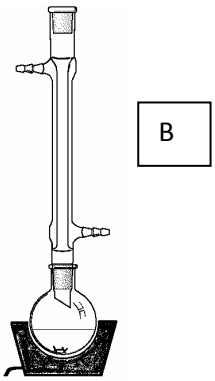
Mass spectrometry (MS), gas chromatography (GC), high-performance liquid chromatography (HPLC) and thin-layer chromatography (TLC) are all used in analytical chemistry.

(*i*) Give **one** application of mass spectrometry. (4)
(*ii*) Give an application of thin-layer chromatography (TLC) in forensic science. (6)
(*iii*) Give an application of high-performance liquid chromatography (HPLC) in the food industry. (6)
(*iv*) State the principle on which all chromatographic techniques are based. (9)

2007 Question 1

A group of students prepared a sample of soap in a school laboratory. A mixture of about 4 g of fat, 2 g of sodium hydroxide and 25 cm^3 of ethanol was refluxed for about 30 minutes. The apparatus was then rearranged and the reaction flask heated to remove the ethanol by distillation. Then the residue in the distillation flask was dissolved in a little boiling water and the mixture poured onto brine (saturated sodium chloride solution). The solid soap separated and it was collected by filtration. The soap was washed with a little ice-cold water. Some of the arrangements of apparatus used are drawn on the right.





(*a*) Which of the arrangements of apparatus (**A** or **B**) was used for
(*i*) the reflux, (*ii*) the distillation stage of the preparation? (8)
(*b*) Draw a rough sketch of either arrangement of apparatus in your answer-book and clearly indicate which part of the condenser should be connected to the cold water tap. (6)
(*c*) Why was ethanol added to the fat and the sodium hydroxide? What else should have been added to the reaction flask before heating was commenced? (12)
(*d*) Why was only a small amount of boiling water used to dissolve the residue remaining in the distillation flask after the distillation? (6)
(*e*) When the soap was collected by filtration it was washed with a little ice-cold water.
Why was it important to wash the soap? (6)
(*f*) A small amount of the soap produced in this experiment was added to test tubes containing
different water samples and the mixtures were shaken.
What would you expect to observe if the water used was
(i) deionised,(*ii*) from a hard water region? (12)

2007 Question 4 (j)

What *type* of organic reaction is involved in the preparation of ethene from ethanol, represented by the following equation?

$$C_2H_5OH \rightarrow C_2H_4 + H_2O$$

2007 Question 8 (d)

Answer the questions below with reference to the compounds **A**, **B** and **C**.

C_2H_2	C_2H_4	C_2H_5Cl
A	**B**	**C**

Compound **B** can be easily converted to compound **C**. Identify the reagent used to bring about this conversion and state the type of reaction involved. (12)

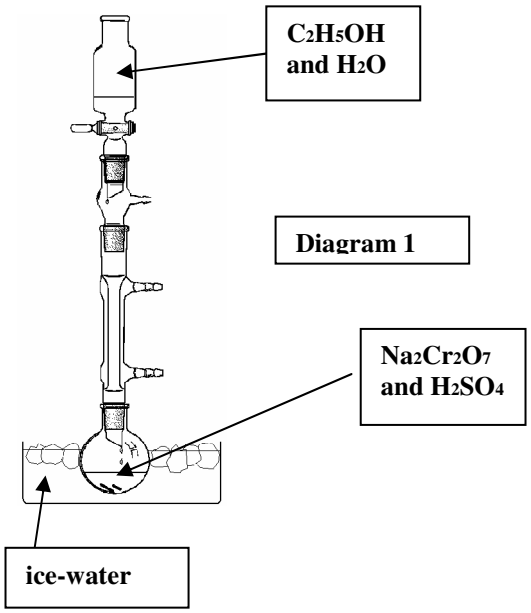
2007 Question 10 (b)

(*i*) What is *chromatography*? (7)
(*ii*) Describe, with the aid of a diagram, how you would separate the indicators in a mixture of indicators using paper chromatography, thin-layer chromatography or column chromatography. (12)
(*iii*) Which of the three types of chromatography in (*ii*) above is used in the separation of dyes taken from fibres in forensic work? (6)

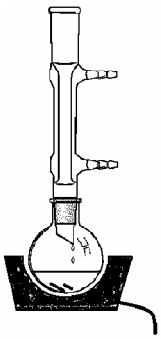
2008 Question 1

A group of students prepared a sample of ethanoic (acetic) acid, **CH_3COOH**, in the school laboratory as follows.

A solution of ethanol, **C_2H_5OH**, in water was added in small portions to an aqueous solution of sodium dichromate(VI), **$Na_2Cr_2O_7$**, and sulfuric acid, **H_2SO_4**, contained in a flask immersed in ice-water (Diagram 1).
When all of the ethanol solution had been added, the reaction mixture was refluxed for about thirty minutes (Diagram 2).
At the end of the reflux period, the apparatus was rearranged and the ethanoic acid was removed from the reaction mixture by distillation (Diagram 3). The ethanoic acid was collected as a fraction which distilled between 115 °C and 118 °C.



(*a*) Make a rough sketch of any one of these arrangements of apparatus in your answer-book and clearly indicate the direction in which the water should flow through the condenser. (8)
(*b*) Explain why small pieces of glass or pumice stone were added to the reaction flask at the start of the experiment. (6)
(*c*) What was the colour of the solution of sodium dichromate(VI) and sulfuric acid in the reaction flask before any of the solution of ethanol and water was added from the dropping



funnel? (6)
(*d*) Why was the solution of ethanol and water added in small portions? (6)
(*e*) What colour was produced as the ethanol reacted with the sodium dichromate(VI)? (6)
(*f*) Why was it important to reflux the reaction mixture? (6)
(*g*) Why was a water bath not suitable for heating the flask during the distillation? (6)
(*h*) A dilute solution (5-6 % w/v) of ethanoic acid (acetic acid) is used in food preservation and as a flavouring agent.
What is the common name of this solution? (6)

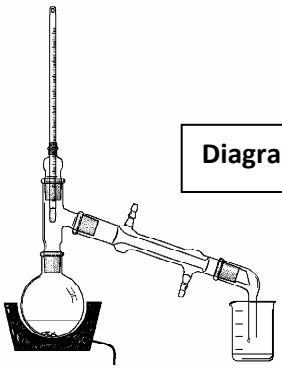


Diagram 3

2008 Question 4 (j)

Identify **one** natural product that is extracted from plant material by steam distillation.

2008 Question 10 (b)

(*b*) Mass spectrometry (MS), gas chromatography (GC), high-performance liquid chromatography (HPLC) and thin-layer chromatography (TLC) are all used in analytical chemistry.
(*i*) In the case of **each** one of these analytical techniques state **one** important application of the technique. (16)
(*ii*) Choose one of these analytical techniques and explain the principle upon which it is based. (9)

2009 Question 8 (a)

In the case of any **four** of the following, describe simple experiments, one in each case,
(*a*) to separate the indicators in a mixture of indicators by chromatography (diagram required),

Options

2004 Question 4 (k)

Answer part **A** or **B**

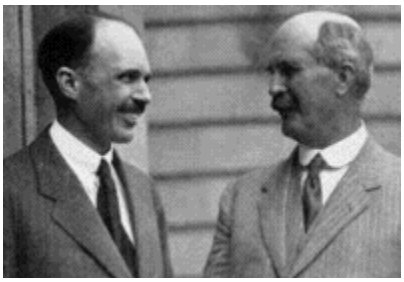
A State **two** factors used to determine choice of location for a chemical industry.
or
B Use a suitable example to explain the term alloy.

2004 Question 11 (c)

Answer part **A** *or* part **B**.
A
Explain the terms (*i*) *feedstock* and (*ii*) *co-products* as used in industrial chemistry. (10)
Explain how batch and continuous processes differ. (9)
Specify **two** ways in which the chemical industry has made a positive contribution to modern life. (6)

Or

B
Name the father and son team pictured on the right who were pioneers in the study of X-ray crystallography. (5)



Pioneers in the study of X-ray crystallography

Copy the table into your answer book and fill in the missing information about the binding forces in each crystal. (15)

Type of crystal	Example	Binding Forces
Ionic	Sodium chloride	
Molecular	Iodine	
Covalent macromolecular	Diamond	

Name the scientist pictured on the right who determined the crystal structures of vitamin B_{12} and penicillin. (5)

The scientist who determined the structures of vitamin B_{12} and penicillin

2005 Question 4 (k)

Answer part **A** or **B**
A What is the chemical formula for ozone? State **one** beneficial effect of the ozone layer.
or
B State **two** general chemical properties of transition metals.

2005 Question 11 (c)

A
Air serves as a major source of both nitrogen gas and oxygen gas.
(*i*) How is oxygen gas produced commercially from air? (4)
(*ii*) State **one** commercial use of oxygen and **one** commercial use of nitrogen. (6)
(*iii*) What is meant by *nitrogen fixation*? Why is it important? (9)
(*iv*) Give **one** way in which nitrogen is fixed in nature. (6)

English scientist who isolated sodium and potassium in the early 1800s

or
B
(*i*) Name the English scientist pictured on the right who isolated the elements sodium and potassium in the early 1800s. (4)
(*ii*) Both sodium and potassium *corrode* easily.
What is meant by *corrosion*? (6)
The corrosion of iron can be prevented by *galvanising*.
(*iii*) How is a piece of iron galvanised? (6)
(*iv*) How does this prevent the iron from corroding? (6)
(*v*) State **one** method, other than galvanising, which helps prevent iron from corroding. (3)

2006 Question 4 (k)

Answer part **A** *or* part **B**.

A State **two** ways in which safety can be promoted at a chemical plant.
or
B Give any **two** characteristic properties of metals.

2006 Question 11 (c)

Answer part **A** *or* part **B**.
A
(*i*) Explain the term *feedstock* in industrial chemistry. (7)
In planning to set up a chemical factory, finding a suitable location and the minimisation of costs, both fixed and variable, are very important considerations.
(*ii*) State any **two** factors that would influence the choice of location for the factory. (6)
(*iii*) Explain the difference between fixed costs and variable costs by giving **one** example in each case. (6)
(*iv*) Name **two** important products of the Irish chemical industry. (6)
or

B
Poly(phenylethene), also known as polystyrene, is a widely-used addition polymer.
(*i*) Explain the underlined term. (7)
(*ii*) Give any **two** common uses of poly(phenylethene). (6)
(*iii*) State any **two** of the procedures involved in the recycling of poly(phenylethene) (6)
(*iv*) Name **one** other addition polymer. (6)

2007 Question 4 (k)

A Give **one** industrial use of nitrogen gas that is based on its lack of chemical reactivity.
or
B Name the process used to recycle scrap iron to produce steel.

2007 Question 11 (c)

Answer part **A** *or* part **B**.
A
A number of gases present in the lower atmosphere are responsible for the greenhouse effect. This effect is generally beneficial, but it has been increasing in recent times, and this increased greenhouse effect is believed to be responsible for various kinds of damage to the environment.
(*i*) What is the *greenhouse effect*? (7)
(*ii*) Name **two** of the gases responsible for causing the greenhouse effect. (6)
(*iii*) Why is the greenhouse effect largely beneficial? (6)
(*iv*) Give **two** kinds of environmental damage that may result from the increased greenhouse effect. (6)
or
B
The diagram shows the electrolysis of molten lead bromide (**$PbBr_2$**) using inert electrodes.
(*i*) Suggest a suitable material for the electrodes. (7)
(*ii*) Identify the product formed at the cathode and also the product formed at the anode. (6)
(*iii*) Why should this electrolysis be carried out in a fume cupboard? (6)
(*iv*) Name the pictured English chemist who coined the terms *electrode, electrolysis*, *anode* and *cathode* in 1832. (6)

2008 Question 4 (k)

Answer part **A** *or* part **B**.

A State **two** ways in which safety can be promoted at a chemical plant.
or
B Give any **two** characteristic properties of metals.

2008 Question 11 (c)

Answer part **A** *or* part **B**.

A
(*i*) Name the main product of the chemical industry on which you carried out a case study.
What use is made of the product you have named? (10)
(*ii*) Name the principal raw material used in this industry.
Give the source of the raw material you have named. (9)
(*iii*) Is the process by which the product is made a *batch* or a *continuous* process?
Explain your answer. (6)

Or

B
In 1964 Dorothy Hodgkin was awarded the Nobel Prize in Chemistry for determining the structures of complex organic molecules.

(*i*) Identify either the vitamin or the antibiotic whose structures were determined by Hodgkin. (4)
(*ii*) What experimental technique did she use to determine these structures? (6)
(*iii*) The father and son team who pioneered this technique are pictured on the right. Who are they? (6)
(*iv*) Give **two** examples of covalent macromolecular solids. (9)

Dorothy Hodgkin

Father and Son

2009 Question 4 (K)

Answer part **A** *or* part **B**.
A What are the two main stages in the manufacture of oxygen from air?
or
B What happens in the process known as galvanising? Why is it carried out?

2009 Question 11 (c)

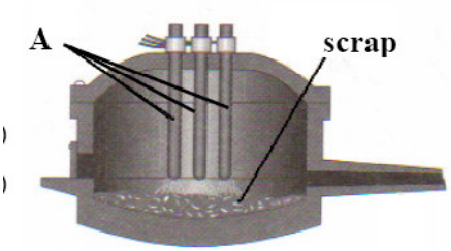
Answer part **A** *or* part **B**.
A Oxides of carbon, nitrogen and sulfur are atmospheric pollutants.
(*i*) Give the name *or* formula of an oxide of carbon other than carbon dioxide.
State **one** harmful effect of this oxide. (7)
(*ii*) Give the name *or* formula of **one** oxide of nitrogen and **one** oxide of sulfur. In the case

of the oxide of sulfur, how would you show that it is an acidic oxide? (9)

(*iii*) Some gaseous acidic oxides combine with moisture in the atmosphere to produce acid rain. Give **two** examples of damage caused by acid rain. (9)

or

B Steel, an alloy of iron, is extracted from scrap (containing iron and/or steel) in a special furnace which is illustrated in the diagram on the right.



(*i*) Name the process involved. (7)

(*ii*) From what material are the electrodes **A** made? (6)

(*iii*) Name the non-metallic element present in steel at concentrations generally less that 1.7%. (6)

(*iv*) Give any **two** uses of steel. (6)