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Leaving Certificate Chemistry Higher Level Examination Paper

SOLUTIONS

CONTENTS

SECTION A

Answer at least two questions from this section.

QUESTION 1

A batch of washing soda crystals (hydrated sodium carbonate, $Na_2CO_3.xH_2O$) had lost some of its water of crystallisation by a process called efflorescence. A chemist was required to determine the percentage water of crystallisation in the crystals and the value of ***x***, the average number of water molecules in the formula.

A sample of the crystals was accurately weighed and found to have a mass of 2.50 g. The sample was dissolved in deionised water and made up to 250 cm^3 of solution. A number of 25.0 cm^3 portions of this solution were titrated with a previously standardised 0.10 M hydrochloric acid (**HCl**) solution. The mean volume of the hydrochloric acid solution required to reach the end point was 21.6 cm^3.

The balanced equation for the titration reaction is:

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

(a) Explain the underlined term. **(5)**

(b) (i) Describe in detail how the chemist should have dissolved the weighed sample of washing soda crystals (ii) and made the solution up to exactly 250 cm^3. **(12)**

(c) (i) State **one** precaution that should have been taken as the end point of the titration was approached. (ii) Explain how this precaution would have contributed to the accuracy of the titration result. **(6)**

(d) (i) Name a suitable indicator for this titration.

(ii) State the colour change in the titration flask at the end point. **(9)**

(e) From the mean volume of the hydrochloric acid solution, calculate the concentration of sodium carbonate (Na_2CO_3) in the original solution in (*i*) moles per litre, (*ii*) grams per litre. **(9)**

(f) (i) Calculate the percentage water of crystallisation in the crystals (ii) and the value of ***x***, (iii) the average number of water molecules in the formula $Na_2CO_3.xH_2O$. **(9)**

SOLUTION

1. (a) Concentration known **(5)**

(b) (i) Wash into beaker of deionised water.

Stir to dissolve.

(ii) Pour through funnel into volumetric flask adding rinsings of beaker.

Bring bottom of meniscus level with mark. **(6 + 3 + 3)**

(c) (i) Add drop by drop. **(3)**

(ii) Add dropwise so that end point will be accurately detected. **(2 × 3)**

(d) (i) Methyl orange. **(3)**

(ii) Yellow to Pink. **(2 × 3)**

(e)

HCl	Na_2CO_3
$V_a = 21.6$	$V_b = 25$
$M_a = 0.1$	$M_b = ?$
$N_a = 2$	$n_b = 1$

$$\frac{v_a \times M_a}{n_a} = \frac{v_b \times M_b}{n_b}$$

$$\frac{21.6 \times 0.1}{2} = \frac{25 \times M_b}{1} \quad \textbf{(3)}$$

$M_a = 0.0432$ moles/L **(3)**

$0.0432 \times 106 = 4.58$ *g/L* **(3)**

(f) (i) Hydrated sodium carbonate = 2.50 g / 250 cm^3

Anhydrous sodium carbonate = 1.14 g / 250 cm^3

Water = 1.36 g / 250 cm^3

$\frac{1.36}{2.5} \times 100 = 54\%$ **(3)**

(ii) Value of *x*

$\frac{0.0108 \text{ moles}}{250 \text{ cm}^3} = \frac{2.5 \text{ g}}{250 \text{ cm}^3}$

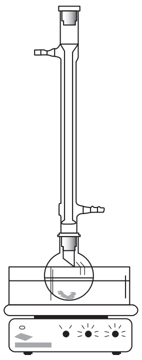
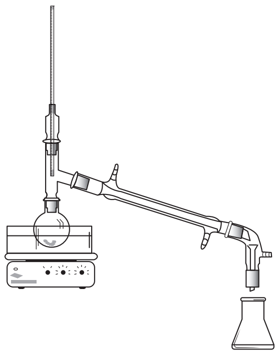
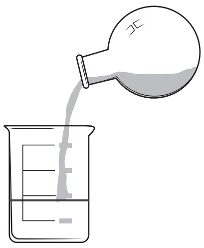
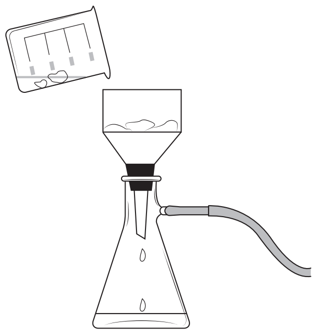
Mass of hydrated sodium carbonate = $\frac{2.5}{0.018} = 231.5$ **(3)**

(iii) $Na_2CO_3 .x H_2O = 231.5$

$106 + 18x = 231.5$

$x = 6.9$ **(3)**

QUESTION 2

Stage 1 Reflux	Stage 2 Distil	Stage 3 Decant	Stage 4 Filter
			

A student prepared a sample of soap in the school laboratory. The experiment was carried out in the four stages illustrated above. At Stage 1, using a water bath, the student refluxed for approximately 20 minutes 4.45 g of glyceryl tristearate (an animal fat) together with an excess of sodium hydroxide pellets, anti-bumping material and about 30 cm^3 of ethanol. The reaction shown in the following balanced equation took place.

$$\begin{array}{l} C_{17}H_{35}COOCH_2 \\ \quad\quad | \\ C_{17}H_{35}COOCH \quad + \quad 3NaOH \quad \rightarrow \quad 3C_{17}H_{35}COONa \quad + \quad \text{co-product} \\ \quad\quad | \\ C_{17}H_{35}COOCH_2 \end{array}$$

glyceryl tristearate — soap (sodium stearate)

The apparatus was then allowed to cool and rearranged for Stage 2, distillation, again using a water bath. After distillation, the contents of the distillation flask were decanted or washed into a beaker containing brine – Stage 3. Filtration was used in Stage 4 to isolate the soap which was then thoroughly washed.

(a) (i) What is the purpose of refluxing in Stage 1 of the preparation?

(ii) Name the type of reaction that occurred during this stage. **(8)**

(b) What substance was removed by distillation in Stage 2? **(3)**

(c) Explain the function of the brine in Stage 3. **(6)**

(d) (i) Why was it necessary to wash the soap thoroughly in Stage 4?

(ii) How should the student have washed the soap? **(6)**

(e) (i) Draw the structure *or* give the name of the co-product of the reaction.

(ii) Where was the co-product located at the end of the process? **(9)**

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(f) Given that the sodium hydroxide was in excess, calculate the maximum yield in grams of soap that could have been obtained in this preparation. **(12)**

(g) Suggest, with reference to its structure, how a soap like sodium stearate can dissolve both the non-polar oils *and* the ionic salts in sweat from the skin. **(6)**

SOLUTION

2. **(a)** (i) To allow time for reaction. Without losing volatile material. **(3 + 2)**

(ii) Saponfication **(3)**

(b) Ethanol **(3)**

(c) To precipitate the soap. **(6)**

(d) (i) To remove sodium hydroxide. **(3)**

(ii) Brine (salt solution) **(3)**

(e) (i) Propane-1,2,3-triol **(6)**

(ii) In the brine **(3)**

(f) $\frac{4.45}{890}$ **(3)** = 0.005 mol of fat **(3)**

0.005 x 3 = 0.015 mol of soap **(3)**

0.015 x 306 = 4.59g **(3)**

(g) $C_{17}H_{35}$ {hydrocarbon part} is non-polar and dissolves oils.

$–COO^-Na^+$ {ionic part} attracted to salts in sweat. **(6)**

QUESTION 3

An experiment to investigate the effect of temperature on the rate of the reaction between 0.05 M sodium thiosulfate solution and an excess of 3 M hydrochloric acid solution was carried out as follows. A timer was started as 5 cm^3 of the acid were added to 100 cm^3 of the sodium thiosulfate solution in a conical flask and a value was obtained for the time taken for the reaction to progress to a certain observable stage. The reciprocal of this time (1/time) was taken as an approximate measure of the initial rate of the reaction. This procedure was repeated at a number of different temperatures. The temperatures and their corresponding reaction times and rates are shown in the table below.

Temperature (°C)	Time (s)	1/Time (s^{-1})
0	976	0.001
12	485	0.002
23	182	0.005
30	99	0.010
39	53	0.019
47	33	0.030
57	20	0.050

(a) Explain the term *rate of reaction*. **(5)**

(b) (i) (1) Describe *and* (2) explain the change observed in the conical flask during the reaction.

(ii) Describe how this observed change was used to obtain the reaction times. **(12)**

(c) Plot a graph of reaction rate (1/time) *versus* temperature. **(12)**

(d) (i) Describe *and* (ii) explain the relationship shown in your graph between rate of reaction and temperature. **(9)**

(e) Use your graph to find the value for the reaction time at 35 °C. Give your answer correct to the nearest second. **(6)**

(f) (i) What would be the effect on the reaction times if the experiment were repeated using 0.025 M sodium thiosulfate solution? (ii) Justify your answer. **(6)**

TIP: Must be given to the nearest second for full marks.

SOLUTION

3. **(a)** Change in concentration per unit time of one reactant or product. **(5)**

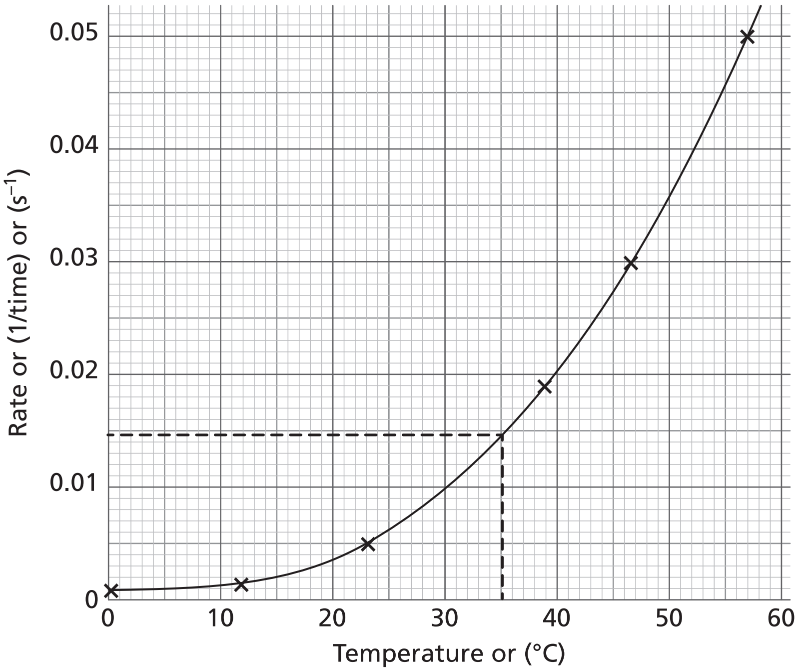
(b) (i) (1) Precipitate. **(3)**

(2) Formation of sulfur. **(3)**

(ii) Stand flask on cross.

Note time on stop clock when cross becomes invisible. **(2 × 3)**

(c) Both axes labelled with correct units
Correct scale on axes
6 points correctly plotted
Correct curve **(4 × 3)**



(d) (i) Rate increases with temperature.
Exponentially. **(2 × 3)**
(ii) More collisions reach activation energy. **(3)**

(e) Rate from graph = 0.0145 s^{-1} [0.014–0.015] **(3)**

Time = $\frac{1}{0.0145}$ = 69s **(3)**

(f) (i) Reaction times double original values.
(ii) Rate directly proportional to thiosulfate concentration. **(2 × 3)**

SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

(a) What colour is observed in a flame test on a salt of (i) barium, (ii) lithium?

(b) Describe the structure of Thomson's 'plum pudding' model of the atom.

(c) Write a balanced nuclear equation for the beta-particle decay of the $^{223}_{87}$**Fr** nucleus.

(d) The scientist pictured on the right is Werner Heisenberg.
State the famous principle, published in 1927, which bears his name.

(e) How many (i) sigma bonds, (ii) pi bonds, result from sharing of the valence electrons between the atoms in a molecule of nitrogen?

(f) What is meant by *one mole* of a substance?

TIP: Definition required here

(g) Find the empirical formula of a compound containing 40% sulfur and 60% oxygen, by mass.

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(h) Potassium iodide (**KI**) is sometimes added to table salt to supplement diets low in iodide ion (I^-). Calculate the daily mass of potassium iodide needed to supply 0.15 mg of iodide ion, the Recommended Daily Amount (RDA) for normal human thyroid function.

(i) Give **two** structural features of hydrocarbons with high octane numbers.

(j) State **two** processes that are carried out during the primary treatment of sewage.

(k) Answer part **A** *or* part **B**.

A Give **two** uses for the oxygen gas produced by the fractionation of liquid air.

or

B State **two** advantages of anodising aluminium.

SOLUTION

4. (a) (i) Green (ii) Crimson **(2 × 3)**

(b) Mass of positively-charged material with electrons embedded in it. **(2 × 3)**

(c) ${}^{223}_{87}\mathbf{Fr} \rightarrow {}^{223}_{88}\mathbf{Ra} + {}^{0}_{-1}e$ **(2 × 3)**

(d) Position and velocity of an electron cannot be known simultaneously **(2 × 3)**

(e) (i) 1 sigma (ii) 2 pi **(2 × 3)**

(f) Amount containing as many particles as the number of atoms of 12g of carbon-12 **(2 × 3)**

(g) $\frac{40}{32} = 1.25$; $\frac{60}{16} = 3.75$

Ratio of S to O 1 : 3 **(3)**

SO_3 **(3)**

(h) $\frac{0.15}{127} = 0.00118 \times 166 = 0.196$ mg **(2 × 3)**

(i) Short chains

Branched

Rings **(any 2 × 3)**

(j) Screening

Passing over grit channels

Settlement (sedimentation) **(any 2 × 3)**

(k) **A** Steel-making

Breathing aid **(2 × 3)**

B Corrosion resistance

Protection **(2 × 3)**

QUESTION 5

(a) (1) Name the scientist whose work on energy levels in the hydrogen atom is depicted in the Google doodle reproduced on the right.

TIP: *Energy level* and *atomic orbital*: Definitions required here

(2) Distinguish between the terms *energy level* and *atomic orbital*. **(14)**

(3) Write the electron configuration *(s, p)* of an atom of silicon showing the distribution of electrons in atomic orbitals in the ground state. **(6)**

(4) Hence, state how many (i) main energy levels, (ii) atomic orbitals, are occupied in the silicon atom in its ground state. **(6)**

(b) (1) Define *first ionisation energy.* **(6)**

(2) Explain why the first ionisation energy value of silicon is

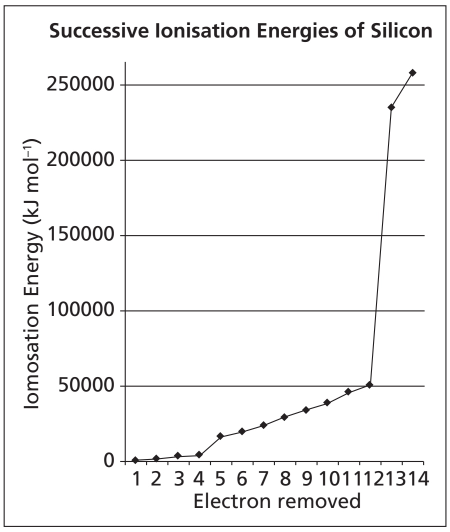
(i) Greater than that of aluminium,

(ii) Less than that of carbon. **(9)**

(c) The successive ionisation energies of silicon are shown in the graph on the right.

(i) Explain how the graph provides evidence for energy levels in the silicon atom. **(6)**

(ii) What other experimental evidence do we have for the existence of energy levels in atoms? **(3)**



SOLUTION

5. (a) (1) Bohr **(5)**

(2) Fixed energy of an electron in an atom **(3)**

Region in space where there is a high probability of finding an electron. **(2 × 3)**

(3) $1s^22s^22p_x^22p_y^22p_z^23s^23p_x^13p_y^1$ **(6)**

(4) (i) 3

(ii) 8 **(2 × 3)**

(b) (1) The minimum energy required to remove the most loosely-bound electron from an isolated gaseous atom in its ground state. **(2 × 3)**

(2) (i) Greater nuclear charge smaller atomic radius. **(2 × 3)**

(ii) Greater atomic radius. **(3)**

(c) (i) Sharp increase in ionisation energy for removal of 5th electron as it is the first to be removed from the 2nd shell.

Sharp increase in ionisation energy for removal of 13th electron as it is the first to be removed from the 1st shell.

Gradual increase in ionisation energies for the first 4 electrons (same shell), 5th to 12th electrons (same shell) and 13th to 14th electrons (same shell) **(any 2 × 3)**

(ii) Line emission spectra of elements **(3)**

QUESTION 6

The fuel in camping gas cylinders, like the one pictured on the right, is a liquefied mixture of propane, butane, and another compound which is a structural isomer of butane.

(a) (i) Name the homologous series to which propane and butane belong.

(ii) Draw the structural formula of propane. **(8)**

(b) Propane and butane have boiling points of –42.1 °C and –0.5 °C, respectively. Explain why propane has a lower boiling point than butane. **(6)**

(c) (i) What is meant by saying that compounds are *structural isomers*? (ii) Draw the structural formula of the isomer of butane. **(12)**

(d) (i) Define *heat of combustion*.

(ii) Write the balanced equation for the complete combustion of butane in an adequate supply of oxygen.

(iii) Calculate the heat of combustion of butane, given that the heats of formation of carbon dioxide, water and butane are –393.5, –285.8 and –125.7 kJ mol^{-1}, respectively. **(24)**

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SOLUTION

6. (a) (i) Alkanes

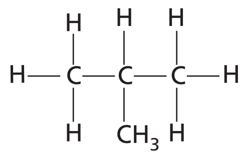
(ii) $CH_3CH_2CH_3$ **(5 + 3)**

(b) Propane is smaller with fewer electrons.

Therefore weaker intermolecular forces between molecules. **(2 × 3)**

(c) (i) Compounds having the same molecular formula but different structural formulas. **(2 × 3)**

(ii)



(6)

(d) (i) Heat change when 1 mole of a substance is burned completely in excess oxygen **(2 × 3)**

(ii) $C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$ (Formulas **(3)** balancing **(3)**)

(iii) $4C + 4O_2 \rightarrow 4CO_2$ $\Delta H = -1574$ kJ **(3)**

$5H + \frac{5}{2}O_2 \rightarrow 5H_2O$ $\Delta H = -1429$ kJ **(3)**

$C_4H_{10} \rightarrow 4C + 5H_2$ $\Delta H = 125.7$ kJ **(3)**

$C_4H_{10} + \frac{13}{2}O_2 \rightarrow 4CO_2 + 5H_2O$ $\Delta H = -2877.3$ kJ mol^{-1} **(3)**

QUESTION 7

Nitrous acid (**HNO_2**) is a weak acid that is readily oxidised to the strong acid, nitric acid (**HNO_3**).

(a) Distinguish between a *strong acid* and a *weak acid* according to the Brønsted-Lowry theory. **(8)**

(b) Nitrous acid dissociates in water as follows:

$$HNO_2 + H_2O \rightleftharpoons H_3O^+ + NO_2^-$$

Identify the two substances acting as bases in this equilibrium. **(6)**

(c) (i) Define pH.

The pH of a 0.2 M solution of nitrous acid is 2.0 at a temperature of 25 °C.

(ii) Calculate the concentration of **H_3O^+** ion in this solution in moles per litre.

(iii) Explain clearly how this **H_3O^+** ion concentration confirms that nitrous acid is a *weak* acid.

(iv) What concentration of nitric acid would have the same **H_3O^+** ion concentration?

(v) Calculate the **OH^-** ion concentration in both of these acidic solutions. **(18)**

(d) Nitric acid and its salts contain the nitrate ion (**NO_3^-**).

Describe in detail how you could test for the presence of the nitrate anion in aqueous solution. **(12)**

(e) Explain how high nitrate levels can result in a reduction in the dissolved oxygen content of lakes and rivers. **(6)**

SOLUTION

7. (a) Strong acid: good proton donor.

Weak acid: poor proton donor. **(5 + 3)**

(b) H_2O

NO_2^- **(2 × 3)**

(c) (i) $-\log_{10}[H^+]$ **(3)**

(ii) $[H_3O^+]$ = inverse $\log_{10}(-2) = 0.01$ M **(3)**

(iii) Concentration of hydronium ions is lower than 0.2M. **(3)**

(iv) 0.01M **(3)**

(v) $[H_3O^+][OH^-] = 1 \times 10^{-14}$ **(3)**

$[OH^-] = 1 \times 10^{-14} \div 0.01 = 1 \times 10^{-12}$ M **(3)**

(d) Add freshly-prepared iron (II) sulphate solution

Trickle concentrated sulphuric acid dropwise down side of test-tube

Brown ring forms at junction of the two liquids **(6 + 2 × 3)**

(e) Causes rapid growth of water plants

Surface plants block light preventing (reducing) photosynthesis **(2 × 3)**

QUESTION 8

Answer the questions that follow with reference to hydrocarbons **A**, **B** and **C** below.

C_2H_2	C_2H_4	C_2H_6
A	**B**	**C**

(a) (i) Give the IUPAC name and (ii) draw the structural formula of compound **B**. **(5)**

(b) Draw a labelled diagram to show how a sample of compound **A** can be prepared and collected in the school laboratory. **(12)**

(c) Describe a chemical test to distinguish between samples of compounds **B** and **C**. **(9)**

(d) Hydrocarbon **C** reacts with chlorine gas (**Cl_2**) in the presence of ultraviolet light.

(i) Name the type of mechanism by which this reaction takes place.

(ii) Give a detailed description of the mechanism of this reaction.

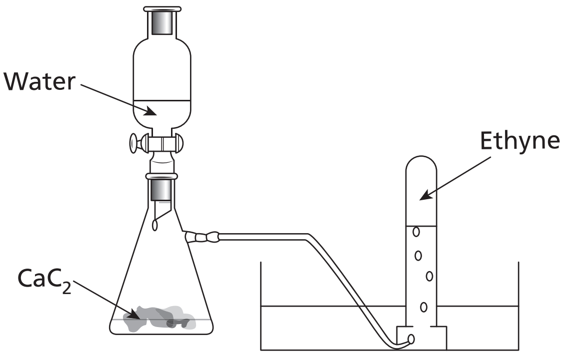
(iii) Explain clearly how the occurrence of another hydrocarbon in the product mixture provides evidence for the mechanism. **(24)**

SOLUTION

8. (a) (i) Ethene

(ii) $CH_2 = CH_2$ **(3 + 2)**

(b)



Water dropping on to

Calcium(II) dicarbide

Delivery tubing shown

Collection of ethyne over water in test-tube **(4 × 3)**

(c) Bromine solution *or* Acidified potassium manganate (VII)

Initial colour of bromine (brown) *or* Initial colour of potassium manganate (VII) (purple)

Solution goes colourless in case of B. **(3 × 3)**

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(d) (i) Free radical substitution **(3)**

(ii) Initiation

A chlorine molecule splits into 2 free chlorine radicals by UV light **(3)**

$Cl_2 \rightarrow 2Cl$

Propagation

A chlorine radical reacts with a molecule of ethane giving hydrogen chloride and an ethyl radical **(3)**

$Cl + C_2H_6 \rightarrow HCl + C_2H_5$

Propagation

The ethyl radical reacts with a molecule of chlorine giving monochloroethane and a chlorine radical **(3)**

$C_2H_5 + Cl_2 \rightarrow C_2H_5Cl + Cl$

Propagation step repeats until one reactant is used up. **(3)**

Termination

Remaining radicals combine to form molecules **(3)**

$2Cl \rightarrow Cl_2$

$Cl + C_2H_5 \rightarrow C_2H_5Cl$

$2C_2H_5 \rightarrow C_4H_{10}$

(iii) Traces of butane from the combining of 2 ethyl radicals **(6)**

QUESTION 9

Consider the following reversible reaction

$$2NO_{(g)} \rightleftharpoons N_{2(g)} + O_{2(g)} \qquad \Delta H = -183 \text{ kJ}$$

that has an equilibrium constant (K_c) value of 20.25 at a certain high temperature *T*.

(a) Write the equilibrium constant expression for the reaction. **(5)**

(b) Calculate the number of moles of nitrogen gas (**N_2**) in the reaction mixture at equilibrium when a 2 mole sample of nitrogen monoxide decomposes to nitrogen gas and oxygen gas in a closed container at temperature *T*. **(12)**

(c) (1) State *Le Châtelier's principle*. **(6)**

(2) What effect, if any, would an increase in (i) the temperature, (ii) the pressure, have on the value of K_c for this reaction?

TIP: Definition required here.

(3) Justify your answer in each case. **(12)**

(d) This reaction is one of several that occur in the catalytic converters fitted to car exhausts. Since the exhaust gases are in the catalytic converter of the car for a very short time (0.1–0.4 seconds), the rate of reaction must be very high.

(i) Name two of the metals used as catalysts in catalytic converters.

(ii) What type of catalysis occurs?

(iii) Give **one** way that the catalysts increase the rate of reaction.

(iv) Name a substance that could 'poison' the catalysts of the catalytic converter. **(15)**

SOLUTION

9. **(a)** $Kc = \frac{[N_2]\,[O_2]}{[NO]^2}$ **(5)**

(b)

	2NO	N_2	O_2
Initial	2	0	0
Change	$-2x$	$+x$	$+x$
At Equilibrium(L)	$2 - 2x$	x	x **(3)**

$\frac{(x)^2}{(2-2x)^2} = 20.25$ **(3)**

$\frac{x}{2-2x} = 4.5$ **(3)**

$x = 0.9$ moles **(3)**

(c) (1) If system at equilibrium is subjected to a stress it tends to oppose the stress **(2 × 3)**

(2) (i) Value decreases

(ii) No effect **(2 × 3)**

(3) (i) Reaction shifts in an endothermic direction to oppose the added heat

(ii) Only temperature change affects K_c **(2 × 3)**

(d) (i) Platinum palladium rhodium **(any 2 × 3)**

(ii) Surface adsorption or heterogeneous **(3)**

(iii) Lower activation energy **(3)**

(iv) Lead compounds **(3)**

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) Study the reaction scheme below and answer the questions that follow with reference to the compounds **X**, **Y** and **Z**, each of which has two carbon atoms in its molecules.

(i) Give a major use for compound **Z**. **(4)**

(ii) Draw the structure of aldehyde **Y** showing the bonding between the atoms. **(6)**

(iii) (1) Draw the structural formula of the ester formed from compounds **X** and **Z**.

(2) Identify any carbon atom in this ester that is in planar geometry. **(9)**

(iv) How could aldehyde **Y** be reduced to alcohol **X**? **(6)**

(b) Define (i) mass number, (ii) relative atomic mass. **(9)**

Three of the five fundamental processes that occur in mass spectrometry are *detection, acceleration and vaporisation of substance*.

(1) What are the two other fundamental processes that occur in mass spectrometry? **(6)**

(2) List all five processes in the order in which they occur. **(3)**

(3) A sample of the element gallium is composed of 60.1% gallium–69 and 39.9% gallium–71. Calculate the relative atomic mass of gallium from this information. **(7)**

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(c) Define oxidation in terms of (i) electron transfer, (ii) change in oxidation number. **(6)**

Use oxidation numbers to identify (iii) the oxidising agent, (iv) the reducing agent, in the following reaction.

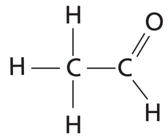
$$Cd + H^+ + NO_3^- \rightarrow Cd^{2+} + NO + H_2O \quad \textbf{(12)}$$

Hence, or otherwise, balance the equation. **(7)**

SOLUTION

10. (a) (i) In vinegar **(4)**

(ii)



(2 × 3)

(iii) (1) CH_3COOCH_3 **(6)**

(2) Carbonyl carbon **(3)**

(iv) Hydrogen

Nickel **(2 × 3)**

(b) (i) Number of protons and neutrons in the atoms of an isotope **(3)**

(ii) Average mass of the isotopes of an element taking their abundances into account

Relative to $\frac{1}{12}$ of mass of carbon-12 atom. **(2 × 3)**

(1) Ionisation to form positive ions separation. **(2 × 3)**

(2) Vaporisation, ionisation, acceleration, separation, detection. **(3)**

(3) $69 \times 60.1 = 4146.9$ **(2)**

$71 \times 39.9 = 2832.9$ **(2)**

100 atoms = 6979.8

$A_r = 69.798$ (69.8) **(3)**

(c) (i) Loss of electrons.

(ii) Increase in oxidation number. **(2 × 3)**

(iii) Oxidising agent: NO_3^-

$+5 \rightarrow +2$ **(2 × 3)**

(iv) Reducing agent: Cd

$0 \rightarrow +2$ **(2 × 3)**

$3Cd + 8H^+ + 2NO_3^- \rightarrow 3Cd^{2+} + 2NO + 4H_2O$ **(7)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) (i) Define *electronegativity*. **(6)**

Ammonia (**NH_3**) and silane (**SiH_4**) are small molecules, each of which has four electron pairs in the valence shell of the central atom.

(ii) Account for the difference in bond angle between the two molecules, 107.3° in ammonia and 109.5° in silane. **(6)**

(iii) Use electronegativity values to determine which bond, the N–H bond in ammonia or the Si–H bond in silane, is the more polar. **(3)**

(iv) Which of the two substances has hydrogen bonding between its molecules? Justify your answer. **(6)**

(v) Give the reason why a molecule with polar bonds can be non-polar. **(4)**

(b) When crystals of ammonium dichromate [**$(NH_4)_2Cr_2O_7$**] are heated strongly, they decompose fully according to the following balanced equation.

$$(NH_4)_2Cr_2O_7 \rightarrow Cr_2O_3 + N_2 + 4H_2O$$

When 12.6 g of these crystals were heated strongly, calculate
(i) how many moles of ammonium dichromate reacted, **(6)**
(ii) the mass of chromium(III) oxide (**Cr_2O_3**) formed, **(6)**
(iii) the volume at s.t.p. of nitrogen gas evolved, **(6)**
(iv) the number of molecules of water produced.
How many atoms did this quantity of water contain? **(7)**

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

A

The Earth's human population is now estimated at 7 billion (7×10^9) and is expected to increase to between 8.3 and 10.9 billion by 2050. Rising levels of air pollution are a direct consequence of an increasing global human population. One manifestation of air pollution is the phenomenon of 'acid rain'.

The EPA (Environmental Protection Agency) reported in 2012 that *'Air quality in Ireland is of a high standard across the country and is among the best in Europe'.*

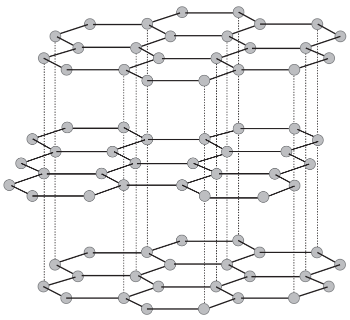
(i) Why is rainwater *always* acidic, even when there is no air pollution? **(4)**
(ii) Outline two damaging effects of 'acid rain' on the environment. **(6)**
(iii) Show, by means of equations, how sulfur dioxide pollution in the atmosphere results in 'acid rain'. **(9)**
(iv) How does human activity contribute to increasing sulfur dioxide levels in the atmosphere? **(3)**
(v) Suggest a reason why Ireland's air quality is of a high standard. **(3)**

or

B

Many solid materials are classified as ionic, molecular, covalent or metallic crystals. Their properties can often be explained in terms of their crystal structures.

(i) Explain the underlined term. **(7)**
(ii) The 'lead' in pencils is actually graphite (mixed with clay). Graphite is a crystalline form of the element carbon. Part of the structure of graphite is shown.
Describe how the bonding in graphite enables it to be used for writing or as a lubricant. **(6)**



(iii) Diamond, another crystalline form of elemental carbon, is the hardest naturally-occurring substance.
Refer to its crystal structure to account for the hardness of diamond. **(6)**
(iv) Explain why metals are often excellent electrical conductors. **(6)**

SOLUTION

11. (a) (i) The relative attraction of an atom for a shared pair of electrons in a covalent bond **(2 × 3)**
(ii) Lone pair of electron has greater repelling power than a bond pair of electrons. Ammonia has three bond pairs (one lone pair) where silane has four bond pairs. **(2 × 3)**
(iii) Electronegativity difference greater for N – H therefore N – H more polar. **(3)**
(iv) Ammonia **(3)**
In ammonia hydrogen bonded to a small, highly electronegative element **(3)**
(v) Centres of positive and negative charge coincide **(4)**

(b) (i) $Mr = 252$ **(3)**
$\frac{12.6}{252} = 0.05$ mol **(3)**
(ii) 0.05 mol $\rightarrow$ 0.05 mol **(3)**
$0.05 \times 152 = 7.6$g **(3)**

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(iii) 0.05 mol → 0.05 mol **(3)**

$0.05 \times 22.4 = 1.12l$ **(3)**

(iv) 0.05 mol → 0.2 mol **(2)**

$0.2 \times 6 \times 10^{23} = 1.2 \times 10^{23}$ **(2)**

$3 \times 1.2 \times 10^{23} = 3.6 \times 10^{23}$ **(3)**

(c) A

(i) Due to dissolved carbon dioxide (CO_2) **(4)**

(ii) Damage to plants (trees)

Corrosion **(2 × 3)**

(iii) $SO_2 + H_2O \rightarrow H_2SO_3$ **(3)**

$SO_2 + \frac{1}{2}O_2 \rightarrow SO_3$

$SO_3 + H_2O \rightarrow H_2SO_4$ **(2 × 3)**

(iv) Burning fossil fuels **(3)**

(v) Small population **(3)**

B

(i) Solids consisting of particles in a lattice **(4 + 3)**

(ii) Layers consisting of hexagons of carbon atoms

Layers can slide over each other **(2 × 3)**

(iii) All covalent bonds between C atoms in a tetrahedral arrangement **(2 × 3)**

(iv) Outer (valence) electrons are delocalised

Electrons are free to move. **(2 × 3)**

SECTION A

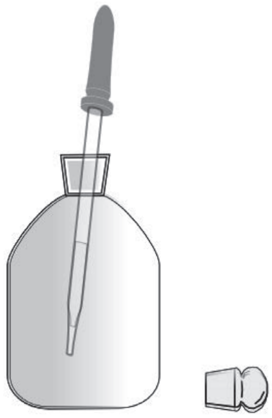
Answer at least two questions from this section.

QUESTION 1

In an experiment to measure the dissolved oxygen content of a river water sample, a small amount of a concentrated solution of compound **A**, followed by a small amount of a concentrated solution of alkaline potassium iodide (**KOH/KI**), were added to a bottle filled with the river water.

These additions were made using the method shown in the diagram, avoiding the addition of bubbles of air. After both additions the stopper was replaced carefully and the bottle was inverted several times to ensure thorough mixing of the contents. A brown precipitate was observed at this stage.

About 1cm^3 of concentrated sulfuric acid (**H_2SO_4**) was then added, allowing the acid to run down the inside wall of the bottle. Again the bottle was stoppered and inverted several times to ensure thorough mixing.



(a) Why was it important to avoid trapping air bubbles each time the stopper was inserted into the sample bottle and when using the dropper? **(5)**

(b) Identify compound **A**. **(3)**

(c) What was observed on addition of the concentrated sulfuric acid followed by the mixing of the contents of the bottle? **(3)**

After the three additions, the thoroughly mixed contents of the sample bottle were titrated in 200cm^3 portions with a 0.02 M solution of sodium thiosulfate (**$Na_2S_2O_3$**). The average titre was 9.4cm^3.

The balanced equation for the titration reaction is:

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

(d) Describe how the burette was (i) rinsed and (ii) filled for use in the titrations. **(15)**

(e) Name the indicator used in the titrations. **(3)**

(f) Calculate the concentration of iodine (**I_2**) in the sample bottle in moles per litre.

For every **one** mole of dissolved oxygen (**O_2**) in the water sample, **two** moles of iodine (**I_2**) are liberated in this experiment. Calculate the concentration of dissolved oxygen in the river water sample

(i) in moles per litre,

(ii) in grams per litre,

(iii) in ppm. **(15)**

(g) What conclusion should have been reached had a white precipitate been observed instead of the brown precipitate after the first two additions of reagents to the bottle filled with river water? **(3)**

(h) Kits, designed for use in the field, allow the dissolved oxygen concentration to be measured immediately on collection of the sample. Why is the *immediate* determination of dissolved oxygen considered best practice? **(3)**

SOLUTION

1. (a) More oxygen (O_2) would dissolve. **(5)**

(b) Manganese(II) sulphate. **(3)**

(c) A brown solution. **(3)**

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(d) (i)
- Rinse with deionised water.
- Rinse with thiosulfate solution. **(2 × 3)**

(ii)
- Add solution to burette and clamp vertically.
- Ensure burette is vertical.
- Use a funnel to fill.
- Remove funnel before adjusting to mark.
- Mark at eye-level.
- Open tap to fill jet (part below tap). **(Any 3 × 3)**

(e) Freshly prepared starch solution. **(3)**

(f) (i) I_2 $Na_2S_2O_3$

$V_{ox} = 50$ $V_{red} = 9.4$

$M_{ox} = ?$ $M_{red} = 0.02$

$n_{ox} = 1$ $n_{red} = 2$

$$\frac{V_{ox} \times M_{ox}}{n_{ox}} = \frac{V_{red} \times M_{red}}{n_{red}}$$

$$\frac{200 \times x}{1} = \frac{9.4 \times 0.02}{2}$$ **(3)**

$x = 0.00047$ moles/L of I_2 **(3)**

$0.00047 \div 2 = 0.000235$ moles/L of O_2 **(3)**

(ii) $0.000235 \times 32 = 0.00752$g/l **(3)**

(iii) $0.00752 \times 1000 = 7.52$ppm **(3)**

(g) There was almost no dissolved oxygen in the water. **(3)**

(h) Biochemical reactions such as respiration or photosynthesis occur. **(3)**

QUESTION 2

In a practical examination, chemistry students were required to perform a number of tasks in a laboratory. They had access to all the necessary reagents and glassware and also to the required safety equipment and clothing.

(a) How could a student have carried out a simple chemical test to confirm that a colourless liquid sample was ethanoic acid and not ethanol? **(5)**

(b) A sample of ethene gas was supplied in a stoppered test tube. Describe fully how the gas could have been shown to be unsaturated. **(12)**

(c) Describe with the aid of a labelled diagram how a student could have used chromatography to separate a mixture of indicators. **(12)**

(d) One of the tasks in the practical examination was to measure the melting points of two benzoic acid samples (**A** and **B**) and to use the results to determine which was the purer sample. The melting points obtained by one of the students were as follows: sample **A** = 117–120°C; sample **B** = 120–121°C.

(i) Which was the purer sample? (ii) Justify your answer. **(6)**

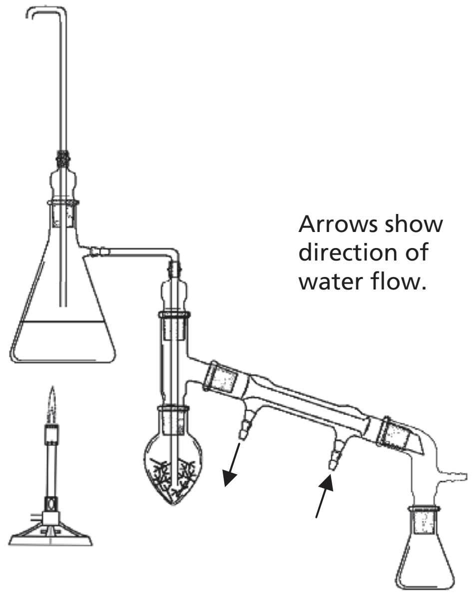
The students were required to recrystallize the impure benzoic acid.

(iii) What solvent should they have used for the recrystallization?

(iv) Explain why this solvent is suitable. **(9)**

(e) The diagram shows a steam distillation apparatus assembled **incorrectly** by one of the students.

Identify the flaw in the assembly and state how it should have been rectified. **(6)**

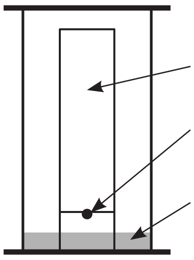


SOLUTION

2. **(a)** Ethanoic acid. Addition of acidified potassium permanganate will not give a colour change. **(5)**

(b) Add a bromine solution to a test tube of ethene. **(3)**
Colour change: Brown **(3)**
to colourless. **(6)**

(c)



Paper chromatography.
Apply mixture using dropper spot on paper
slightly above eluent
in beaker (tank).
Solvent moves up separating components. **(4 × 3)**

(d) (i) B **(3)**
(ii) A has wider range. **(3)**
(iii) Water. **(3)**
(iv) Very soluble in hot but slightly soluble in cold. **(6)**

(e) Have end of safety tube under water. **(6)**

QUESTION 3

A reaction vessel of negligible heat capacity held 75cm^3 of 1.0M **HCl** solution at a temperature of 13.0°C. A thermometer was placed in the liquid in the reaction vessel. A graduated cylinder was used to measure out and add 75cm^3 of 1.0M **NaOH** solution at a temperature of 15.0°C to the reaction vessel. The highest temperature of the reaction mixture was recorded as 20.9°C.

This information was used to calculate the heat of reaction of hydrochloric acid with sodium hydroxide. The equation for the reaction is:

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

(a) Define *heat of reaction*. **(5)**

(b) Suggest a suitable material for the reaction vessel to avoid heat loss to the surroundings. **(3)**

(c) State (i) one advantage, (ii) one disadvantage, of the use of a burette instead of a graduated cylinder for measuring out the base and adding it to the reaction vessel. **(6)**

(d) State **two** ways of ensuring that the rise in temperature was measured as accurately as possible. **(6)**

(e) (i) How many moles of **HCl** were neutralised in the reaction with **NaOH**?
(ii) Calculate the heat produced in the reaction vessel as a result of the reaction of the **HCl** with the **NaOH**. Take the density and the specific heat capacity of the reaction mixture – assumed equal to those of water – as 1.0gcm^{-3} and 4.2kJ kg^{-1} K^{-1} respectively.
(iii) Hence calculate the heat of reaction for the neutralisation reaction between hydrochloric acid and sodium hydroxide. **(18)**

(f) The solutions used in this experiment were moderately concentrated.
(i) Identify the hazard associated with the use of these solutions.
(ii) Describe *or* draw the warning symbol that should have been used to label the two solutions.
(iii) What experimental problem would have been encountered if 0.1M **NaOH** and 0.1M **HCl** solutions had been used instead of 1.0M solutions? **(12)**

SOLUTION

3. **(a)** Heat change that occurs when the numbers of moles of reactants in the balanced equation react completely. **(5)**

(b) Polystyrene. **(3)**

(c) (i) More accurate. **(3)**

(ii) Two $50cm^3$ burettes needed. **(3)**

(d) Use sensitive thermometer (to within 0.2°C).
Add quickly.
Avoid splashing.
Cover quickly.
Stir. **(Any 2 × 3)**

(e) (i) $\frac{75 \times 1}{1000} = 0.075$ moles **(3)**

(ii) Mass: $75 + 75 = 150cm^3 = 150g = 0.15kg$ **(3)**

Temperature rise: $20.9 - \frac{(15.0 + 13.0)}{2} = 6.9K$ **(3)**

$0.15 \times 4.2 \times 6.9 = 4.347kJ$ **(3)**

(iii) 0.075 liberates 4.437kJ

I mole liberates:

$\frac{4.347}{0.075}$

$= -57.96kJ$ **(6)**

(f) (i) Corrosive. **(6)**

(ii)

(3)

(iii) Very small temperature rise. **(3)**

SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

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

(b) Define *relative atomic mass*.

(c) How many neutrons are there in 0.14g of carbon-14?

(d) Give the shape and the corresponding bond angle for a molecule of formula $\mathbf{QX_4}$ where **Q** is an element from Group 4 of the periodic table.

(e) When hydrogen gas was passed over 1.59g of copper oxide, 1.27g of metallic copper were produced. Find by calculation the empirical formula of the copper oxide.

(f) Complete and balance the equation for the chemical reaction that occurs when a piece of sodium is added to ethanol: $\mathbf{C_2H_5OH} \quad + \quad \mathbf{Na} \quad \rightarrow$

(g) What reagents are needed to test a solution for the nitrate ion?

(h) State *Charles' law*.

(i) What happens during secondary sewage treatment?

(j) What is meant by *heterogeneous* catalysis?

(k) Answer part **A** *or* part **B**.

A Write a balanced equation for the formation of calcium silicate (a component of slag) from calcium oxide in steelmaking.

or

B Write a balanced equation for the formation of ozone in the stratosphere.

SOLUTION

4. **(a)** $1s^2 2s^2 2p^6$

$3s^2 3p^6 3d^{10} 4s^2$ **(2 × 3)**

(b) Average mass of atoms of an element, relative to $\frac{1}{12}$ mass of carbon-12 atom. **(2 × 3)**

(c) $0.14 \div 14 = 0.01 \text{ mol} \times 6 \times 10^{23} = 6 \times 10^{21}$ atoms **(3)**

6×10^{21} atoms $\times 8 = 4.8 \times 10^{22}$ neutrons **(3)**

(d) Tetrahedral. **(3)**

109.5° **(3)**

(e) Mass of copper = 1.27g; mass of oxygen = 1.59 – 1.27 = 0.32

$\frac{1.27}{63.5} = 0.02$

$\frac{0.32}{16} = 0.02$ **(3)**

Empirical formula = CuO **(3)**

(f) $2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2$

TIP: Formulas **(3)**, Balancing **(3)**.

(g) Iron(II) sulfate. **(3)**

Concentrated sulfuric acid. **(3)**

(h) At constant pressure **(3)**

the volume of a fixed mass of gas is directly proportional to temperature measured on the Kelvin scale. **(3)**

(i) Oxidation. **(6)**

(j) Reactant and catalyst in different phases. **(6)**

(k) **A:** $CaO + SiO_2 \rightarrow CaSiO_3$

TIP: Formulas **(3)**, Balancing **(3)**.

B: $O + O_2 \rightarrow O_3$

TIP: Formulas **(3)**, Balancing **(3)**.

QUESTION 5

(a) The 350th anniversary of Robert Boyle's discovery of the relationship between the pressure and the volume of a fixed mass of gas at constant temperature is commemorated in this Irish stamp issued in 2012.

Boyle also contributed to the development of the use of the term *element* in Chemistry.

What was his understanding of this term? **(5)**

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(b) (i) Use Bohr's atomic theory of 1913 to account for the emission spectrum of the hydrogen atom. **(15)**

TIP: Five relevant points are required to achieve the full 15 marks. Use bullet points, making as many points as you can.

(ii) Explain, in terms of atomic structure, why different flame colours are observed in flame tests using salts of different metals. **(6)**

(iii) What colour is observed in a flame test on lithium chloride?

(iv) Describe the testing procedure. **(9)**

(c) Further research and scientific discoveries, including Heisenberg's uncertainty principle (1927), led to significant modification of Bohr's original atomic structure theory of 1913.

(i) Explain the underlined term.

(ii) Give **one** other factor that also contributed to the need for modification of Bohr's 1913 theory.

These modifications included the introduction of the idea of atomic orbitals.

(iii) What is an *atomic orbital*? **(15)**

SOLUTION

5. (a) An element cannot be broken into anything simpler by chemical means. **(5)**

(b) (i)
- The electron in a hydrogen atom occupies fixed energy levels.
- In the ground state electrons occupy the lowest available energy levels.
- The electron can move to a higher energy level if it receives a certain amount of energy.
- The energy absorbed must exactly equal the energy difference between ground state and excited state.
- Excited state is unstable and the electron falls back to a lower level.
- Emitting the excess energy in the form of a photon of light. **(Any 5 × 3)**

(ii) Metal atoms of different elements have different sets of energy levels and different electron configurations.
Therefore, they emit different frequencies of light.
Therefore, they have different spectra. **(2 × 3)**

(iii) Red. **(3)**

(iv) Place the salt on platinum wire.
Hold it at top of flame. **(2 × 3)**

(c) (i) It is not possible to measure at the same time the exact position and velocity of an electron. **(2 × 3)**

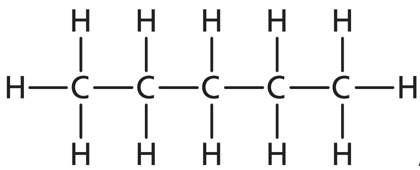
(ii) Wave nature of electron. **(3)**

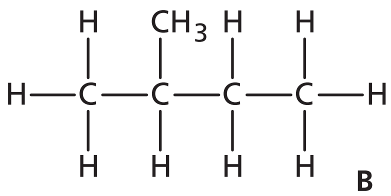
(iii) Region around the nucleus of an atom where there is a high probability of finding an electron. **(2 × 3)**

QUESTION 6

(a) Define the *octane number* of a fuel. **(5)**

(b) Compound **A** is obtained from the fractional distillation of crude oil and is converted to compound **B** by isomerisation.


A


B

(i) Give the systematic (IUPAC) names for **A** and **B**.

(ii) Explain the term *isomerisation*. Draw the structural formula of another isomer of **A** and **B**.

TIP: Note there are two separate parts to (b)(ii).

(iii) Predict whether **A** or **B** has the higher octane number. Justify your answer. **(21)**

(c) Ethyne is produced from calcium carbide and water according to the following balanced equation:

$$CaC_{2\,(s)} + 2H_2O_{(l)} \rightarrow C_2H_{2\,(g)} + Ca(OH)_{2\,(s)}$$

Calculate the heat change for this reaction given that the heats of formation of calcium carbide, water, ethyne and calcium hydroxide are –59.8, –285.8, 227.4 and –985.2KJ mol^{-1} respectively. **(15)**

(d) Describe the structure of benzene in terms of

(i) the bonding between the carbon atoms and the hydrogen atoms,

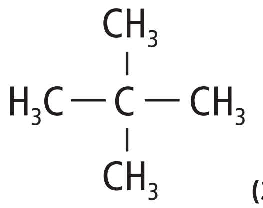
(ii) the bonding between the carbon atoms. **(9)**

SOLUTION

6. (a) Measure of tendency to auto-ignite. **(5)**

(b) (i) **A:** Pentane. **(3)**
B: 2-methylbutane. **(3)**

(ii) Changing straight chain molecules into branched chain molecules that have the same molecular formula. **(2 × 3)**



(3)

(iii) B. **(3)**
Shorter chain. **(3)**

(c)

CaC_2	$\rightarrow$	Ca	+	2C	ΔH	= 59.8kJ **(3)**
$2H_2O$	$\rightarrow$	$2H_2$	+	O_2	ΔH	= 571.6kJ **(3)**
$2C + H_2$	$\rightarrow$	C_2H_2			ΔH	= 227.4kJ **(3)**
$Ca + O_2 + H_2$	$\rightarrow$	$Ca(OH)_2$			ΔH	= −985.2kJ **(3)**
$CaC_2 + 2H_2O$	$\rightarrow$	C_2H_2	$+ Ca(OH)_2$		ΔH	= −126.4kJ **(3)**

(d) (i) Sigma. **(3)**

(ii) Sigma. **(3)**
Pi bonds **(3)**

QUESTION 7

(a) Define the *rate of a chemical reaction*. **(5)**

(b) Explain clearly why there is an almost instantaneous reaction between aqueous solutions of sodium chloride and silver nitrate. **(6)**

(c) When hydrogen gas and nitrogen gas are mixed in a ratio of 3:1 by volume at room temperature in a sealed container, the formation of ammonia (**NH_3**) is very slow.

(i) Suggest **two** ways to increase the rate of this reaction.

(ii) Explain how each of the ways you suggest speeds up the reaction. **(12)**

(d) (i) Describe how you would measure the reaction time when $10cm^3$ of 1.0M hydrochloric acid solution and $50cm^3$ of 0.20M sodium thiosulfate solution react according to the following balanced equation:

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

(ii) If you were given additional sodium thiosulfate solutions of the following concentrations: 0.04M, 0.08M, 0.12M and 0.16M, describe how you would show that the rate of this reaction is directly proportional to the concentration of the sodium thiosulfate solution. **(18)**

(e) Draw a reaction profile diagram for an exothermic reaction indicating clearly on your diagram

(i) the activation energy (E_A) for the reaction, (ii) the heat of reaction (ΔH). **(9)**

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SOLUTION

7. (a) Change in concentration per unit time of any one reactant or product. **(5)**

(b) They are ionic compounds. **(6)**

(c) (i) Increased pressure. **(3)**
Increased temperature. **(3)**

(ii) *Increased pressure*:
Closer molecules means more collisions per unit time.
Increases energy of molecules.

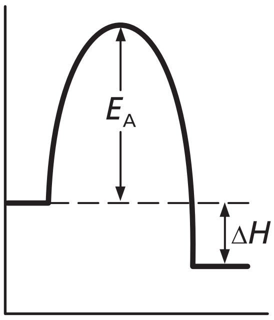
Increased temperature:
More collisions reach activation.
More effective collisions. **(Any 2 × 3)**

(d) (i) Place the thiosulfate solution in a vessel over a cross (mark) on a white surface.
Add the HCl and start a stopclock.
Note the time when the cross becomes invisible. **(3 × 3)**

(ii) Repeat the above procedure for each of the given solutions.
Find the reciprocals of the times plot $\frac{1}{t}$ against concentration.
Plot of rate against concentration gives a straight line through the origin (0, 0). **(3 × 3)**

(e) (i)

(ii)



(9)

QUESTION 8

Study the reaction scheme and answer the questions that follow.

(a) Ethane and ethene belong to the <u>homologous series</u> of alkanes and alkenes, respectively.

(i) Explain the underlined term.

(ii) What type of reaction was involved in conversion **X**?

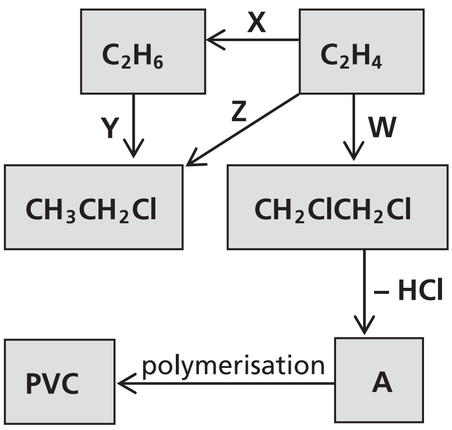
(iii) How does the geometry around the carbon atoms change as a result of conversion **X**? **(15)**

(b) Identify the reagent required to bring about (i) conversion **Y**, (ii) conversion **Z**, (iii) conversion **W**. **(9)**

(c) Describe the mechanism of reaction **W**. **(12)**

(d) Draw the structure of **A** and give its name. **(9)**

(e) Draw the structure of two repeating units of PVC. **(5)**



SOLUTION

8. (a) (i) Same general formula.
Differ from the previous by CH_2.
Similar chemical properties.
Gradation in physical properties.
Similar method of preparation. **(Any 1 × 6)**

(ii) Addition. **(3)**

(iii) Planar **(3)**
to tetrahedral. **(3)**

(b) (i) Chlorine. **(3)**

(ii) Hydrogen chloride. **(3)**

(iii) Chlorine. **(3)**

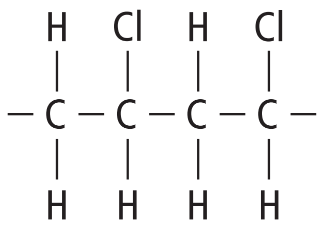
(c) Polarisation of chlorine molecule by double bond;
followed by heterolytic fission of chlorine molecule.

Addition of Cl^+ to the double bond;
forming a localised carbonium ion.

Addition of chloride ion (Cl^-) to the intermediate to give 1,2-dichloroethane. **(4 × 3)**

(d) CH_2=CHCl **(6)**
1-chloroethene **(3)**

(e)



(5)

QUESTION 9

(a) (i) What is meant by *chemical equilibrium*? (ii) Why is a chemical equilibrium described as *dynamic*? **(8)**

(iii) State *Le Châtelier's principle*. **(6)**

(b) When a yellow solution of iron(III) chloride (**$FeCl_3$**) and a colourless solution of potassium thiocyanate (**KCNS**) were mixed in a test tube, a red colour appeared and the following equilibrium was established:

$$\underset{\text{yellow}}{Fe^{3+}_{(aq)}} + CNS^-_{(aq)} \rightleftharpoons \underset{\text{red}}{Fe(CNS)^{2+}_{(aq)}}$$

Explain

(i) the effect on the **Fe^{3+}** ion concentration of adding **KCNS** to the equilibrium mixture,

(ii) why changing the pressure has no effect on this equilibrium. **(9)**

(c) (i) Write the equilibrium constant (K_c) expression for this reaction. **(6)**

A mixture of 1.0×10^{-3} moles each of iron(III) chloride and potassium thiocyanate was allowed to come to equilibrium in 1 litre of solution at room temperature according to the equation above. It was found that 1.1×10^{-4} moles **$Fe(CNS)^{2+}$** were present in the solution at equilibrium.

(ii) Calculate the value of the equilibrium constant (K_c) for the reaction. **(12)**

(d) The red colour faded when the test tube containing the equilibrium mixture was placed in an ice-water bath.

(i) State whether the value of K_c for this reaction is bigger or smaller at the lower temperature.

(ii) Is the forward reaction exothermic *or* endothermic? (iii) Justify your answer. **(9)**

SOLUTION

9. (a) (i) A state in which the rate of the forward reaction equals the rate of the reverse reaction. **(5)**

(ii) Reaction has not stopped. **(3)**

(iii) If a system at equilibrium is subjected to a stress **(3)**
it tends to oppose the stress. **(3)**

(b) (i) Decrease. **(3)**
Reaction shifts forward to oppose stress. **(3)**

(ii) Equilibrium in solution – no gases involved. **(3)**

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(c) (i) $K_c = \frac{[Fe(CNS)^{2+}]}{[Fe^{3+}][CNS^-]}$ **(6)**

(ii)

	Fe^3	CNS^-	$Fe(CNS)^{2+}$
Initial	1.0×10^{-3}	1.0×10^{-3}	0
Change	$-1x$	$-1x$	$+1x$
At equilibrium (L)	8.9×10^{-4} **(3)**	8.9×10^{-4} **(3)**	1.1×10^{-4}

$K_c = \frac{1.1 \times 10^{-4}}{(8.9 \times 10^{-4})^2}$ **(3)**

$= 138.87$ **(3)**

(d) (i) Smaller. **(3)**

(ii) Endothermic. **(3)**

(iii) Cooling shifts the reaction in the backwards direction – exothermic direction. **(3)**

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) (1) Distinguish between *intramolecular* bonding and *intermolecular* forces. **(7)**

(2) Explain each of the following in terms of intramolecular bonding *or* intermolecular forces *or* both.

(i) The boiling point of hydrogen (20K) is significantly lower than that of oxygen (90.2K).

(ii) Iodine has a very low solubility in water.

(iii) When a charged rod is held close to a thin stream of water flowing from a burette, the stream of water is deflected. **(18)**

(b) The following redox reaction is highly exothermic and is used to produce molten iron for welding pieces of steel together, e.g. sections of railway track:

$$8Al + 3Fe_3O_4 \rightarrow 4Al_2O_3 + 9Fe$$

(i) (1) Define *oxidation* in terms of change in oxidation number.

(2) Show using oxidation numbers that this is a redox reaction.

(3) Identify the reducing agent. **(12)**

(ii) (1) What mass of aluminium powder is required to produce 1008g of molten iron for a single railway track weld?

(2) What mass of aluminium oxide is produced as waste in the process? **(13)**

(c) Caesium-137 is a radioactive isotope of the alkali metal caesium. Caesium-137 was released into the atmosphere when Japanese nuclear reactors were damaged by a tsunami in 2011. Caesium-137 decays by beta-particle emission with a half-life of 30 days.

(i) Define *radioactivity*. **(6)**

(ii) Give **two** differences between chemical reactions and nuclear reactions. **(6)**

(iii) Give **two** properties of beta-particles. **(6)**

(iv) A certain mass of caesium-137 leaked on a particular day. What fraction of this mass remained as caesium-137 after 90 days? **(7)**

SOLUTION

10. (a) (1) Intramolecular: Forces between atoms in molecules.
Intermolecular: Forces between molecules. **(4 + 3)**

(2) (i) Hydrogen is smaller, therefore weaker intermolecular forces. **(6)**

(ii) Iodine is pure covalent (non-polar). **(3)**
Water is a polar solvent. **(3)**

(iii) Charge on rod attracts **(3)**
opposite charge on polar water molecule. **(3)**

(b) (i) (1) Increase in oxidation number. **(3)**

(2) $8Al + 3Fe_3O_4 \rightarrow 4Al_2O_3 + 9Fe$
Al increased from 0 to +3. **(3)**
Fe decreased from $+2\frac{2}{3}$ to 0. **(3)**

(3) Al. **(3)**

(ii) (1) 1008g Fe ÷ 56
= 18 mol **(3)**
= 16 mol Al based on ratio of 9:8 from equation. **(3)**
× 27 = 432g **(3)**

(2) 16 mol Al ≡ 8 mol Al_2O_3 based on ratio of 8:4 from equation. **(2)**
× 102 = 816g **(2)**

(c) (i) Spontaneous random decay of a nucleus. **(6)**

(ii) Chemical: Involves electrons.
No change to nucleus.
Nuclear: Electron cloud not involved.
Nuclear change. **(Any 2 × 3)**

(iii) Negative charge.
Negligible mass. **(2 × 3)**

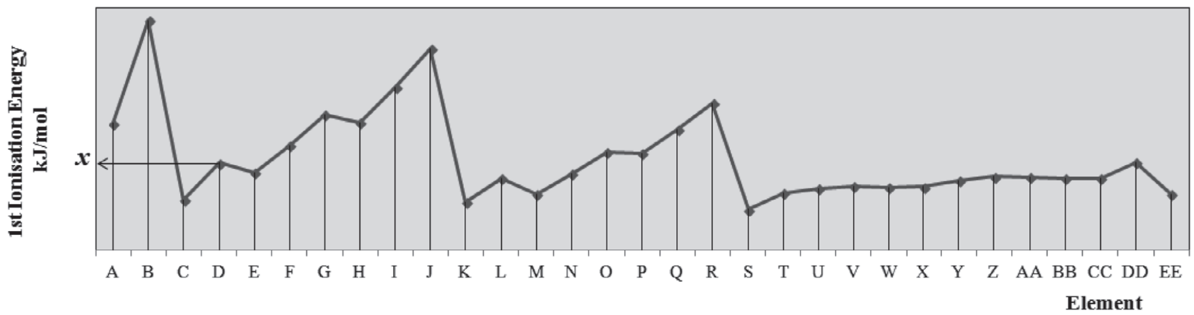
(iv) One-eighth. **(7)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) Define *first ionisation energy*. **(7)**

The graph shows the first ionisation energy values, displayed in order of increasing atomic number, for the first 31 elements of the periodic table. Refer to the table of first ionisation energy values on page 80 of the *formulae and tables booklet*.



(i) (1) Name the elements labelled **B** and **P** in the graph.

(2) What is the numerical value of ***x***? **(9)**

(ii) What is the principal reason for the large decrease in first ionisation energy between the elements labelled **R** and **S**? **(3)**

(iii) Explain why the first ionisation energy value of the element labelled **H** is lower than that of the element labelled **G**. **(6)**

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(b) Define a base according to (i) the Arrhenius theory, (ii) the Brønsted–Lowry theory. **(7)**

Give (i) the conjugate acid, (ii) the conjugate base, of HPO_4^{2-}. **(6)**

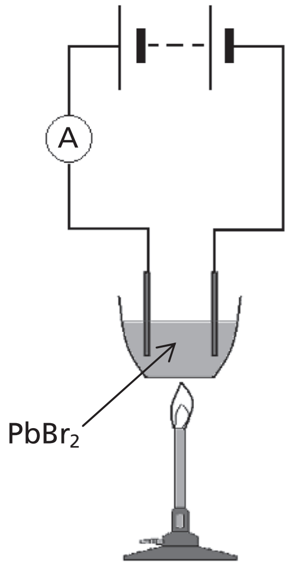
Ammonium hydroxide (NH_4OH) is produced by dissolving gaseous ammonia in water.

Calculate the pH of an ammonium hydroxide solution that contains 7.0g NH_4OH per litre. The value of the base dissociation constant (K_b) for ammonium hydroxide is 1.8×10^{-5}. **(12)**

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

A

An arrangement to demonstrate the electrolysis of molten lead bromide ($PbBr_2$) using inert electrodes is shown in the diagram. The demonstration is carried out in a fume cupboard.



(i) What is meant by *electrolysis*? **(4)**

(ii) Why must the lead bromide be molten? **(3)**

(iii) Suggest a suitable material for the electrodes. **(3)**

(iv) Write balanced half equations for the reactions that occur at the electrodes during the electrolysis. **(9)**

(v) Name a metal, other than lead, that is extracted from one of its compounds by electrolysis.

Name the compound that is electrolysed to produce this metal. **(6)**

or

B

Answer the following questions with respect to the chemical industry.

(i) Distinguish between the terms *feedstock* and *raw materials* in the chemical industry. **(6)**

(ii) Explain whether labour costs are a fixed cost or a variable cost. **(6)**

(iii) Why are glass and steel widely used as the materials for the reaction vessels in the chemical industry? **(3)**

(iv) Give one advantage of a batch process and one advantage of a continuous process. **(6)**

Select one of the following Irish manufacturing industries:

ammonia manufacture **Cobh (now closed)**	**nitric acid manufacture** **Arklow (now closed)**	**periclase manufacture** **Drogheda**

Give a reason why the process you chose was located at the site mentioned. **(4)**

SOLUTION

11. (a) Minimum energy required to remove the most loosely bound electron from a gaseous atom in its ground state. **(4 + 3)**

(i) (1) B is helium. **(3)**
P is sulphur. **(3)**
(2) 900 **(3)**

(ii) R has full outer sublevel. **(3)**

(iii) H has lower first ionisation energy because it has a less stable electron configuration than G. Half filled 2*p* sublevel G has higher first ionisation energy because it has a more stable electron configuration than H.
Half-full 2*p*-sublevel is extra stable. **(2 × 3)**

(b) (i) Arrhenius: A base dissociates to produce hydroxyl ions in aqueous solution.

(ii) Brønsted–Lowry: Base is a proton acceptor. **(4 + 3)**

(i) $H_2PO_4^-$ **(3)**

(ii) PO_4^3 **(3)**

$7 \div 35 = 0.2$ moles **(3)**

$[OH^-] = \sqrt{K_b \times M_b}$

$= \sqrt{1.8 \times 10^{-5} \times 0.2}$

$= 0.0019$ **(3)**

$pOH = -\log_{10}[OH^-]$

$= -\log_{10}(0.0019)$

$= 2.72$ **(3)**

$pH = 14 - 2.72 = 11.28$ **(3)**

(c) A (i) Chemical reaction that occurs when electricity passes through an electrolyte. **(4)**

(ii) So that the ions are free to move. **(3)**

(iii) Platinum. **(3)**

(iv) $Pb^{2+} + 2e^- \rightarrow Pb$ **(3)**

$2Br^- \rightarrow Br^2 + 2e^-$

TIP: Formulas **(3)**, Balancing **(3)**.

(v) Sodium. **(3)**

Sodium chloride. **(3)**

B (i) Raw materials: Used to produce feedstock. **(3)**

Feedstock: Materials used in the process. **(3)**

(ii) Fixed costs. **(3)**

Must be paid regardless of level of production. **(3)**

(iii) They are chemically unreactive. **(3)**

(iv) Batch: Versatile. **(3)**

Continuous: Can run for long periods. **(3)**

Ammonia – Cobh:
Availability of natural gas.
Good rail link near port.
Skilled workforce available near university. **(4)**

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SECTION A

Answer at least two questions from this section.

QUESTION 1

A student determined the concentration of a hydrochloric acid solution by titration with 25.0cm^3 portions of a 0.05M primary standard solution of anhydrous sodium carbonate. The portions of sodium carbonate solution were measured into a conical flask using a 25cm^3 pipette. The hydrochloric acid solution was added from a burette. The mean titre was 20.8cm^3.

The balanced equation for the titration reaction was:

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

(a) Explain the underlined term. **(5)**

TIP: Give the definition.

(b) Describe how the student should have prepared 500cm^3 of the 0.05M primary standard solution from a known mass of pure anhydrous sodium carbonate, supplied on a clock glass. **(12)**

TIP: Needs four relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

Calculate the exact mass of anhydrous sodium carbonate (**Na_2CO_3**) required to prepare this solution. **(6)**

(c) (i) Describe how the liquid level in the burette was adjusted to the zero mark.

(ii) Why was a pipette filler used to fill the pipette with 25.0cm^3 of the sodium carbonate solution? **(6)**

(d) (i) Name a suitable indicator for this titration.

(ii) State the colour change observed at the end point. **(9)**

(e) Calculate, correct to two decimal places, the concentration of the hydrochloric acid solution in

(i) moles per litre,

(ii) grams per litre. **(12)**

SOLUTION

1. **(a)** Pure, stable, soluble material from which solutions of known concentration can be made. **(2 + 3)**

(b) Rinse from clock glass into beaker and dissolve.
Pour using funnel into 500cm^3 volumetric flask and add rinsings of beaker.
Add deionised water until bottom of meniscus on mark.
Read at eye level.
Stopper and invert several times. **(Any 4 × 3)**

$\frac{500 \times 0.05}{1000} \times 106$ **(3)**

$= 2.65$g **(3)**

(c) (i) Fill above mark and adjust level until bottom of meniscus is on the graduation mark with tap. **(3)**

(ii) Avoid solution getting into mouth for hygiene reasons. **(3)**

(d) (i) Indicator: Methyl orange. **(3)**

(ii) Colour before: Orange. **(3)**

Colour after: Red. **(3)**

(e) (i) HCl $\qquad Na_2CO_3$

$V_a = 20.8 \qquad V_b = 25$

$M_a = ? \qquad M_b = 0.05$

$n_a = 2 \qquad n_b = 1$

$$\frac{V_a \times M_a}{n_a} = \frac{V_b \times M_b}{n_b}$$

$$\frac{20.8 \times M_a}{2} = \frac{25 \times 0.05}{1} \textbf{ (6)}$$

$M_a = 0.12$ moles/L **(3)**

(ii) $0.12 \times 36.5 = 4.38$g/L **(3)**

QUESTION 2

Ethene gas can be prepared from ethanol in a school laboratory.

(a) Draw a labelled diagram showing the arrangement of apparatus and the reagents used in the preparation and collection of the ethene. **(11)**

(b) It is important to be aware of the possibility of a 'suck-back' occurring when carrying out this procedure.

(i) At what stage in the procedure is a 'suck-back' most likely to occur?

(ii) Give one possible consequence of a 'suck-back' occurring.

(iii) How could a 'suck-back' be avoided? **(9)**

(c) Describe how you could test the gas produced for unsaturation. **(9)**

TIP: Needs three relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

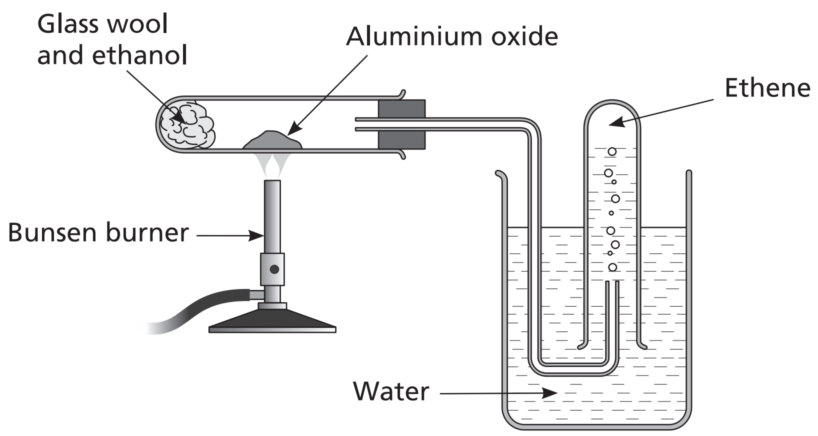
(d) Write a balanced equation for the preparation of ethene from ethanol. **(6)**

(e) When ethanol is converted to ethene by this method, a 60% yield can be expected.

Assuming this percentage yield, what is the maximum number of 75cm^3 test tubes of ethene gas that could be collected at room temperature and pressure when 2.4cm^3 of ethanol, density 0.8 gcm^{-3}, react? **(15)**

SOLUTION

2. (a) Ethanol on glass wool. **(3)**
Aluminium oxide. **(3)**
Heat. **(3)**
Collection over water using trough. **(2)**



(b) (i) When heat is removed. **(3)**

(ii) Cold water sucked into test tube and test tube cracks. **(3)**

(iii) Remove delivery tube from water before removing heat. **(3)**

(c)
- Reagent: Bromine water solution. **(3)**
- Colour before: Red. **(3)**
- Colour after: Colourless. **(3)**

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(d) $C_2H_5OH \rightarrow C_2H_4 + H_2O$ **(6)**

(e) Mass of ethanol = 2.4 × 0.8 = 1.92g **(3)**

1.92/46 = 0.042 **(3)**

0.042 × 24000 = 1008cm^3 **(3)**

60% × 1008 = 605cm^3 **(3)**

$\frac{605}{75}$ = 8 test tubes. **(3)**

QUESTION 3

The relative molecular mass of a volatile liquid can be found by means of a procedure involving the use of either apparatus **A** or apparatus **B** shown below.

(a) Give an example of a liquid suitable for use in this experiment. **(5)**

(b) Describe how (i) the mass, (ii) the volume, of the vapour is determined. **(15)**

(c) Explain why the pressure of the vapour is the same as atmospheric pressure. **(6)**

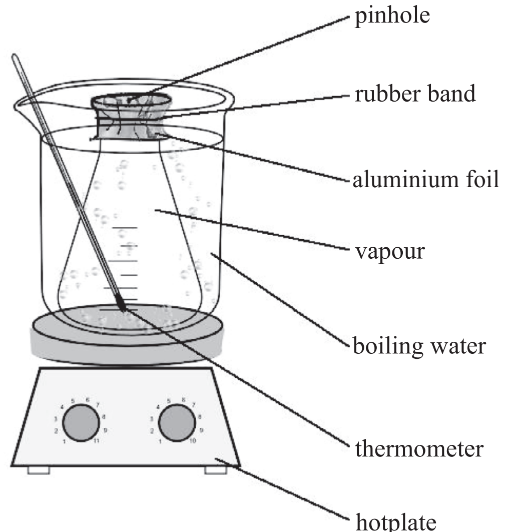
(d) The vapour of 0.63g of a pure liquid occupies a volume of 330cm^3 at a temperature of 100°C and at a pressure of 101kPa.

Calculate the number of moles of vapour and hence calculate the relative molecular mass of the volatile liquid. **(15)**

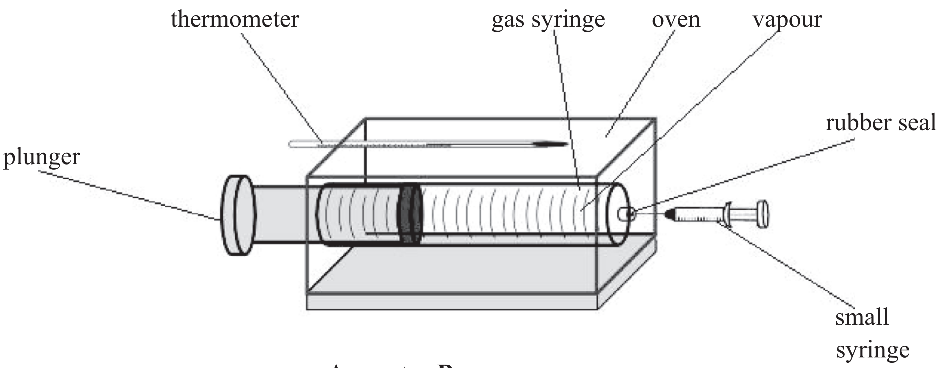
TIP: Change values given to correct units for the ideal gas equation.

(e) (i) Why is this method unsuitable for liquids that are non-volatile?

(ii) What modern instrumental technique could be used as a more accurate method to measure the relative molecular masses of volatile and non-volatile liquids as well as of solid and gaseous substances? **(9)**



Apparatus **A**



Apparatus **B**

SOLUTION

3. **(a)** Propanone. **(5)**

(b) (i) Apparatus A.
Weigh flask and fittings.
Heat until all liquid gone, cool, dry and reweigh.
Find difference between the initial and final mass. **(3 × 3)**

(ii) Fill flask with water and empty into graduated cylinder. **(6)**

(c) The pinhole means that the vapour is exposed to the air. **(2 × 3)**

(d) $PV = nRT$ **(3)**

$$n = \frac{101 \times 10^3 \times 330 \times 10^{-6}}{8.3 \times 373}$$ **(3)**

$= 0.01076$ moles **(3)**

$$\text{Mass} = \frac{0.63}{0.01076}$$ **(3)**

$= 58.6$ **(3)**

(e) (i) Do not vaporise easily. **(3)**

(ii) Mass spectrometer. **(6)**

SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

(a) State the number of (i) sub-levels (subshells), (ii) orbitals, occupied by electrons in an argon atom in its ground state.

(b) Write a balanced nuclear reaction for the beta particle decay of iodine-131.

TIP: See formulae and tables booklet, page 79.

(c) Define *relative atomic mass*.

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

(e) Using oxidation numbers, or otherwise, balance the following equation.

$$\mathbf{Cu + NO_3^- + H^+ \longrightarrow Cu^{2+} + NO_2 + H_2O}$$

(f) State *Avogadro's law.*

(g) Why does raising the temperature generally increase the rates of chemical reactions?

(h) Name (i) the gas, (ii) the ion, formed at the negative electrode when aqueous sodium sulfate solution is electrolysed.

(i) Define *bond energy*.

(j) What happens during the secondary treatment of sewage?

(k) Answer part **A** or part **B**.

A What is the *structural* difference between low density poly(ethene) and high density poly(ethene)?

or

B What happens in the *scrubbing* of waste acidic gases in industry?

SOLUTION

4. **(a)** (i) 5 **(3)**

(ii) 9 **(3)**

(b) ${}^{131}_{53}\text{I} \rightarrow {}^{131}_{53}\text{Xe} + {}^{0}_{-1}\text{e}$ **(6)**

(c) Average mass of atoms of element **(3)**
relative to $\frac{1}{12}$ the mass of a carbon-12 atom. **(3)**

(d) Sigma: Head-on overlap of orbitals. **(3)**
Pi: lateral overlap of *p*-orbitals. **(3)**

TIP: Give definition.

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(e) $Cu + 2NO_3^- + 4H^+ \rightarrow Cu^{2+} + 2NO_2 + 2H_2O$ **(6)**

(f) Equal volumes of gases contain equal numbers of molecules **(3)**
under the same conditions of temperature and pressure. **(3)**

(g) More collisions reach activation energy. **(6)**

(h) (i) Hydrogen. **(3)**
(ii) Hydroxyl ions. **(3)**

(i) Average energy required to break 1 mole of bonds and to separate the atoms completely from each other. **(6)**

(j) Biological **(3)**
oxidation of sewage. **(3)**

(k) **A:** Low: Have branching giving rise to spaces between chains.
High: Very little *or* no branching, giving rise to little space between chains. **(2 × 3)**

B: Lime reacts **(3)**
with waste acidic gases. **(3)**

QUESTION 5

(a) Write the electron configuration (*s, p*) of an oxygen atom showing the arrangement of electrons in atomic orbitals. **(5)**

(b) (i) Define *atomic radius* (*covalent radius*).
(ii) State and (iii) explain the trend in atomic radii (covalent radii) across the second period of the periodic table of the elements. **(12)**

(c) Give **one** reason why electronegativity values exhibit a general increase across the second period of the periodic table. **(3)**

(d) Consider the following hydrides of some of the elements from the second and third periods of the periodic table:

H_2O NH_3 PH_3 HCl

(i) (1) State how the bonding in **PH_3** differs from the bonding in the other three hydrides.
(2) What is the reason for this difference in bonding?

(ii) From these four hydrides, (1) identify the hydride or hydrides in which hydrogen bonding occurs between the molecules.
(2) Give **one** property that is affected by the presence of intermolecular hydrogen bonding in the hydride or hydrides you have identified.

(iii) (1) State the shape of the **PH_3** molecule and (2) explain using electron-pair repulsion theory how this shape arises. **(21)**

(e) Boron trichloride (**BCl_3**) is a colourless gas. (1) Would you expect (i) the **B–Cl** bonds, (ii) the **BCl_3** molecules, to be polar or non-polar? (2) Justify your answers. **(9)**

SOLUTION

5. (a) $1s^2 2s^2 2p^4$ **(3)**
$2px^2 2py^1 2pz^1$ **(2)**

(b) (i) Half the distance between centres of the atoms of singly bonded atoms of the same element. **(6)**
(ii) Decrease in atomic radius. **(3)**
(iii) Increase in effective nuclear charge. **(3)**

(c) Increase in nuclear charge. **(3)**

(d) (i) (1) PH_3 is virtually non-polar and other three are polar covalent. **(3)**
(2) Tiny electronegativity difference in PH_3 but much bigger electronegativity differences in the other three. **(3)**

(ii) (1) H_2O
NH_3 **(2 × 3)**
(2) Higher boiling point. **(3)**

(iii) (1) Pyramidal. **(3)**

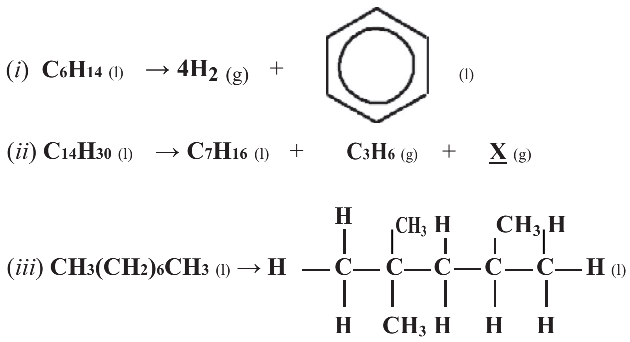
(2) Repulsion between three bond pairs and the one lone pair. **(3)**

(e) (1) (i) B–Cl bond: Polar **(3)**

(ii) BCl_3 molecule: Non-polar **(3)**

(2) Unequal sharing of electrons between B and Cl cancels due to symmetry of molecule. **(3)**

QUESTION 6



(a) Several processes are used in oil refining to convert less useful hydrocarbons into more useful ones. For each conversion, (i) to (iii), name the process involved. **(8)**

(b) (i) Name a hydrocarbon that **X** could be and (ii) draw its structural formula.

(iii) Name the product of process (iii) and state its octane number. **(12)**

(c) (i) Explain why the substance MTBE (methyl *tert*-butyl ether) is sometimes added to motor fuel.

(ii) Name the substance previously added to motor fuel for the same purpose and (iii) state why its use was discontinued. **(9)**

(d) (i) Define *heat of combustion*.

(ii) Name the laboratory apparatus used to measure the heats of combustion of fuels and foodstuffs. **(9)**

(e) Calculate the heat of formation of the hydrocarbon ($\mathbf{C_8H_{18}}$) produced in process (iii), given that its heat of combustion value has been measured to be –5502kJ mol^{-1} and that the heats of formation of carbon dioxide and water are –394 and –286kJ mol^{-1}, respectively. **(12)**

SOLUTION

6. **(a)** (i) Reforming.

(ii) Catalytic cracking.

(iii) Isomerisation. **(3 + 3 + 2)**

(b) (i) But-1-ene. **(3)**

(ii) $CH_2{=}CHCH_2CH_3$ **(3)**

(iii) 2,2,4-trimethylpentane. **(3)**

100 **(3)**

(c) (i) Increase octane number. **(3)**

(ii) Lead compounds. **(3)**

(iii) Toxic. **(3)**

(d) (i) Heat change when 1 mole of a substance is burned completely in excess oxygen. **(2 × 3)**

(ii) Bomb calorimeter. **(3)**

(e)

$8CO_2$	+	$9H_2O$	→	C_8H_{18}	+ $12\frac{1}{2}O_2$	$\Delta H = 5502$kJ **(3)**
8C	+	$8O_2$	→	$8CO_2$		$\Delta H = -3152$kJ **(3)**
$9H_2$	+	$4\frac{1}{2}O_2$	→	$9H_2O$		$\Delta H = -2574$kJ **(3)**
8C	+	$9H_2$	→	C_8H_{18}		$\Delta H = -224$kJ **(3)**

QUESTION 7

(a) (i) Explain how hard water is caused and (ii) how it wastes soap. (iii) How can hard water be softened by ion exchange so that it is suitable for use as deionised water in the laboratory? **(11)**

(b) (1) In water treatment, what is the purpose of adding each of the following: (i) a flocculating agent, (ii) chlorine, (iii) a fluorine-containing compound, (iv) calcium hydroxide, (v) sulfuric acid? **(15)**

(2) State the problem that would arise when each of any **two** of these substances is added in excessive quantity. **(6)**

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(c) (i) Why is water pollution by heavy metal ions, e.g. Hg^{2+} or Pb^{2+}, a cause of concern?
(ii) Name an instrumental technique that could be used to detect and measure the concentration of a heavy metal ion in a water sample.
(iii) Explain how Hg^{2+} or Pb^{2+} ions can be removed from a water supply. **(12)**

(d) Describe a test for the presence of chloride ion (Cl^-) in water. **(6)**

SOLUTION

7. (a) (i) Caused by calcium (magnesium) hydrogencarbonate. **(3)**
(ii) Soap used up in reaction with Ca and Mg ions to give scum. **(3)**
(iii) Pass through resin to replace positive ions with hydrogen ions **(3)** and negative ions with hydroxyl ions. **(2)**

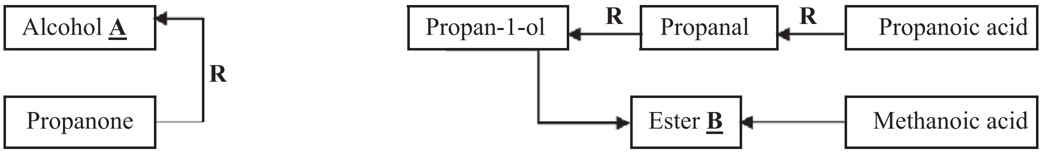
(b) (1) (i) Flocculating agent: Clumping of fine particles. **(3)**
(ii) Chlorine: Kills pathogens. **(3)**
(iii) Fluorine-containing compound: Prevents tooth decay. **(3)**
(iv) Calcium hydroxide: Raises pH. **(3)**
(v) Sulfuric acid: Lowers pH. **(3)**
(2) Chlorine: Water tastes of chlorine. **(3)**
Sulfuric acid: Corrodes pipes. **(3)**

(c) (i) Danger to health. **(3)**
(ii) Atomic absorption spectroscopy. **(6)**
(iii) Precipitation. **(3)**

(d) Add silver nitrate and dilute nitric acid. **(3)**
White precipitate forms. **(3)**

QUESTION 8

Study the reaction scheme and answer the questions that follow.



(a) Give the systematic (IUPAC) name for (i) the alcohol **A**, (ii) the ester **B**. **(8)**

TIP: The full correct name.

(b) Alcohol **A** and propan-1-ol are structural isomers.

TIP: Give the definition.

(i) Explain the underlined term.
(ii) What is the structural difference between a primary alcohol and a secondary alcohol?

TIP: Give the definition of each one.

(iii) Identify another pair of structural isomers from the reaction scheme. **(18)**

(c) Identify a compound in the scheme whose carbon atoms are all in tetrahedral geometry. **(3)**

TIP: Four single bonds.

(d) Name the reagent and catalyst used to bring about the conversions labelled **R**. **(6)**

TIP: Formulas also accepted.

(e) Propanal is oxidised by Fehling's reagent. (i) Describe how this reaction is carried out.
(ii) Why does propanone not react with Fehling's reagent? **(12)**

(f) Which compound in the scheme would you expect to have a fruity odour? **(3)**

SOLUTION

8. (a) (i) Propan-2-ol. **(5)**
(ii) Propyl methanoate. **(3)**

(b) (i) Compounds with the same molecular formula but different structural formula. **(2 × 3)**

(ii) Primary: One carbon attached to OH carbon.
Secondary: Two carbons attached to OH carbon. **(2 × 3)**

(iii) Identify: Propanal and propanone. **(6)**

(c) A – propan-2-ol. **(3)**

(d) Regent: Hydrogen. **(3)**
Catalyst: Nickel. **(3)**

(e) (i) Mix equal amounts of Fehling's A and Fehling's B in a test tube.
Add small amount of propanal.
Heat in water bath.
Red precipitate formed. **(Any 3 × 3)**

(ii) Propanone is not easily oxidised. **(3)**

(f) B – propyl methanoate. **(3)**

QUESTION 9

(a) (i) Define *rate of reaction*. **(5)**

The loss of mass of a mixture of 50cm^3 of a 2M solution of hydrochloric acid and excess marble chips was monitored over time and the following data were recorded.

Loss of mass/g	0.00	0.10	0.18	0.29	0.35	0.39	0.41	0.41
Time/s	0	20	40	80	120	160	220	240

(ii) Plot a graph to show the mass of carbon dioxide produced (loss of mass) *versus* time. **(12)**

(iii) Use your graph to find the instantaneous rate of the reaction at 60 seconds in terms of g/s carbon dioxide produced. **(6)**

(iv) Mark clearly on your graph the curve you would expect to obtain if the reaction were repeated using 50cm^3 of a 1M solution of hydrochloric acid. (v) Justify the (vi) shape and (vii) position of this curve relative to the graph you have plotted. **(9)**

(b) When hydrogen peroxide is added to a warm solution of potassium sodium tartrate, a slow reaction occurs in which tartrate ions are oxidised to carbon dioxide and water. If cobalt(II) ions (**Co^{2+}**) are added as a catalyst, a big increase in the reaction rate is observed.

(i) What type of catalysis is involved in this reaction? **(3)**

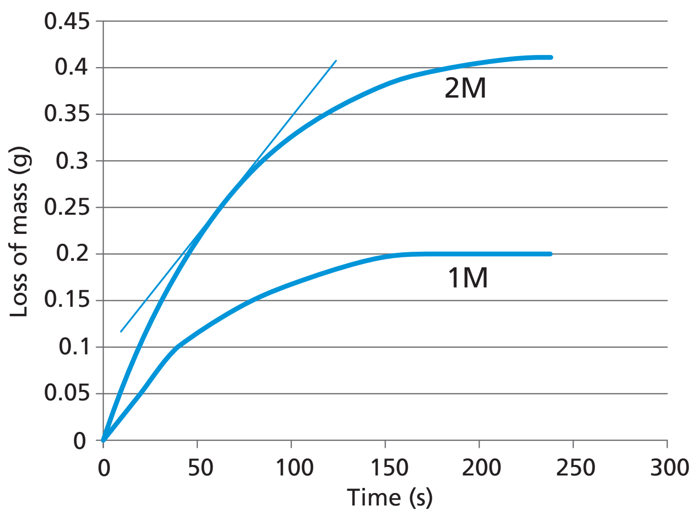
(ii) What colour changes are observed when **Co^{2+}** ions catalyse the reaction? **(6)**

(iii) Explain the significance of the colour changes. **(9)**

SOLUTION

9. **(a)** (i) Change in concentration per unit time of any one reactant or product. **(5)**

(ii)



MARKS:
Axes correctly labelled. **(3)**
Axes correctly scaled. **(3)**
Points correctly plotted. **(3)**
Curve accurately drawn from origin. **(3)**

(iii) Slope of tangent to curve:
$\frac{0.35 - 0.14}{100 - 20} = 2.625 \times 10^{-3}$g/s **(6)**

TIP: 2×10^{-3} to 3×10^{-3} was accepted.

(iv) Rises to half the height. **(3)**

(v) Less steep at the start. **(3)**

(vi) Less steep at the start due to lower concentration of HCl. **(3)**

(b) (i) Homogeneous. **(3)**

(ii) Pink to green back to pink. **(6)**

(iii) Pink at the start is colour of catalyst (Co^{2+}) solution.
Green due to formation of intermediate complex.
Pink at end as catalyst (Co^{2+}) restored. **(3 × 3)**

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) In general, alkenes are more reactive than alkanes. Alkenes undergo addition reactions and alkanes undergo substitution reactions.

(i) Account for the greater reactivity of alkenes compared to alkanes. **(7)**

(ii) (1) Describe the mechanism of the addition of bromine (**Br_2**) to ethene.

(2) State one piece of evidence to support the mechanism you have described. **(18)**

(b) (1) Define *an acid* in terms of the Brønsted–Lowry theory.

(2) What is a *conjugate pair*? **(7)**

A certain water soluble acid–base indicator represented by **HIn** is a weak acid which dissociates as follows in water.

$$\mathbf{HIn} \rightleftharpoons \mathbf{H^+} + \mathbf{In^-}$$

green (HIn) — purple (In^-)

(3) State and explain the colour observed when a few drops of a solution of the indicator are added to a 0.5M **NaOH** solution. **(6)**

(4) Calculate the pH of (i) the 0.5M **NaOH** solution, (ii) a 0.1M solution of the indicator, given that its K_a value is 2.0×10^{-5}. **(12)**

(c) A bracelet, originally made of pure silver, became tarnished over time with black silver sulfide (**Ag_2S**) forming on the surface. The bracelet was cleaned by converting the silver sulfide back to metallic silver using aluminium in the following reaction. The mass of the bracelet decreased by 0.0096g in the cleaning process.

$$\mathbf{3Ag_2S + 2Al \longrightarrow 6Ag + Al_2S_3}$$

(i) What substance was oxidised in this cleaning process? **(4)**

(ii) How many moles of sulfur (**S**) were removed from the bracelet when the silver sulfide (**Ag_2S**) was converted to aluminium sulphide (**Al_2S_3**)? **(6)**

(iii) What mass of aluminium was used in the reaction? **(9)**

(iv) What would the loss in mass of the tarnished bracelet have been if it had been cleaned by the alternative method of removing all of the silver sulfide by polishing? **(6)**

SOLUTION

10. (a) (i) Presence of double bond which is electron rich. **(4 + 3)**

(ii) (1) Mechanism:

Polarisation of Br_2

followed by heterolytic fission-splitting into ions of Br^+ and Br^-.

Addition of bromonium ion across the double bond.

Addition of bromide ion (Br^-) to carbonium ion. **(4 × 3)**

(2) The addition of another anion, e.g. Cl^- or OH^- will compete with the Br^- for the carbonium ion giving either 1-bromo-2-chloroethane or 2-bromoethanol, respectively. **(6)**

(b) (1) Acid: Is a proton donor.

(2) Conjugate pair: Acid and base that differ by one proton. **(4 + 3)**

(3) Purple. **(3)**

Hydroxyl ions remove hydrogen ions causing the reaction (equilibrium) to shift forward. **(3)**

(4) (i) $pOH = -\log_{10}[OH^-]$

$-\log_{10}0.5 = 0.3$ **(3)**

$14 - 0.3 = 13.7$ **(3)**

(ii) $[H^+] = \sqrt{K_a \times M_a}$

$\sqrt{2.0 \times 10^{-5} \times 0.1}$

$= 0.00141$ **(3)**

$pH = -\log_{10}[H^+]$

$= -\log_{10}(0.00141)$

$= 2.85$ **(3)**

(c) (i) Aluminium. **(4)**

(ii) $\frac{0.0096}{32}$ **(3)**

$= 0.0003$ moles **(3)**

(iii) 0.0003 moles of S ≡ 0.0003 moles of Ag_2S **(3)**

≡ 0.0002 moles of Al **(3)**

≡ 0.0054g of Al **(3)**

(iv) 0.0003 mol S ≡ 0.0003 mol Ag_2S **(3)**

× 248 = 0.0744g **(3)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) In 1909 Rutherford bombarded a very thin sheet of gold foil with alpha particles, most of which passed straight through it undeflected. Some alpha particles, however, were deflected at large angles and a very small number were reflected back along their original paths. The first of these observations was not inconsistent with the 'plum pudding' model of the atom that had been proposed by Thomson in 1904, but Rutherford had to formulate a new model of atomic structure to account for the other two observations.

(i) What are alpha particles? **(4)**

TIP: Give the definition.

(ii) Describe the structure of Thomson's 'plum pudding' model of the atom. **(6)**

(iii) Explain why some alpha particles were deflected at large angles as they passed through the gold foil. **(6)**

(iv) Why were some alpha particles reflected back along their original paths? Why did this happen to only a very small number of alpha particles? **(6)**

(v) Draw a labelled diagram to show the new structure of the atom proposed by Rutherford. **(3)**

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(b) Consider the following room temperature equilibrium reaction used to dissolve iodine (I_2) crystals in an aqueous solution of iodide ions (I^-).

$$I_{2\,(aq)} + I^-_{(aq)} \rightleftharpoons I_3^-{}_{(aq)}$$

When 0.0800 moles of iodine crystals and 0.2400 moles of iodide ions were added to deionised water and made up to a litre of solution, 0.0793 moles of triiodide ions (I_3^-) were present at equilibrium.

(i) Write the equilibrium constant (K_c) expression for this equilibrium reaction. **(6)**

(ii) Calculate the value of the equilibrium constant (K_c) for the reaction at room temperature. **(12)**

(iii) State and explain the effect on the equilibrium concentration of triiodide ions of adding a substance that reacts with iodine, e.g. starch. **(7)**

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

A

Bauxite from Africa is transported to Aughinish in Co. Limerick, where it is converted to pure alumina (Al_2O_3). The alumina is then shipped to Russia where aluminium metal is produced from it by electrolysis.

(i) Describe the chemical processes used to produce pure alumina from bauxite. **(12)**

(ii) Draw a labelled diagram of the electrolytic cell used to produce aluminium metal from alumina. **(9)**

(iii) Explain why the recycling of aluminium is environmentally desirable. **(4)**

or

B

(i) Give one major commercial use for nitrogen gas. **(4)**

(ii) Explain why nitrogen gas is chemically inert. **(6)**

(iii) What is meant by the *fixation* of nitrogen gas in the atmosphere? **(6)**

(iv) Describe how atmospheric nitrogen gas is fixed by lightning. **(9)**

SOLUTION

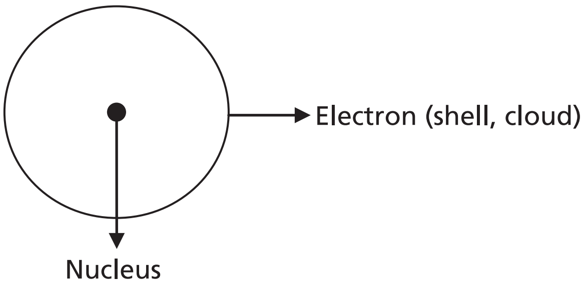
11. (a) (i) Particles with two protons and two neutrons. **(4)**

(ii) Sphere with positive charge spread out over it; with electrons embedded in it. **(2 × 3)**

(iii) Particles were repelled; when passing near nucleus. **(2 × 3)**

(iv) Some collided with nucleus.
But most of an atom is empty space. **(2 × 3)**

(v) **(3)**



(b) (i) $K_c = \frac{[I_3^-]}{[I_2][I^-]}$ **(6)**

(ii)

	I_2	I^-	I_3^-
Initial	0.0800	0.2400	0
Change	−1x	−1x	+1x
At equilibrium (L)	0.0007 **(3)**	0.1607 **(3)**	0.0793

(0.0793)/(0.0007)(0.1607) **(3)**

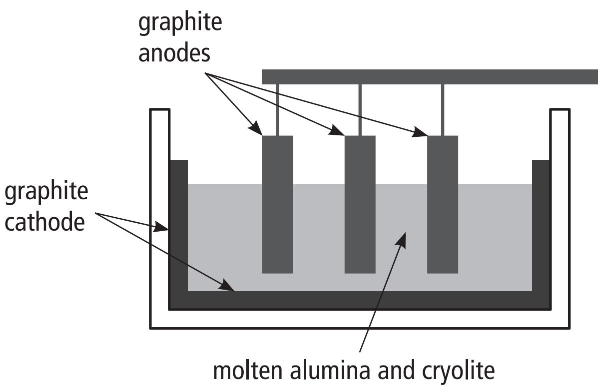
= 704.95 **(3)**

(iii) Concentration of triiodide ions decreases.

Reaction shifts backward to restore iodine concentration. **(4 + 3)**

(c) **A:** (i) Heat bauxite with sodium hydroxide.
Producing soluble sodium aluminate.
Seed with crystals of aluminium oxide trihydrate.
Precipitation of aluminium oxide trihydrate. **(4 x 3)**

(ii)



MARKS:
Graphite anodes labelled.
Graphite cathode labelled.
Molten alumina and cryolite labelled. **(3 × 3)**

(iii) Prevents loss of aluminium. **(4)**

B: (i) In flushing oil tanks. **(4)**

(ii) High energy bond.
Non polar.
Triple bond. **(Any 2 × 3)**

(iii) Conversion of atmospheric nitrogen **(3)**
to useful compounds. **(3)**

(iv) Lightning supplies the high temperature required for N_2 to combust. **(3)**
Nitrogen combines with oxygen to produce nitrogen(II) oxide. **(3)**
NO_2 combines with moisture (H_2O) to give nitrate. **(3)**

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2011 CHEMISTRY Higher Level

SECTION A

Answer at least <u>two</u> questions from this section.

QUESTION 1

A chemist determined the concentration of a bleach solution containing **NaClO** by volumetric analysis. A 25.0cm^3 sample of the bleach was first diluted to exactly 500cm^3.

TIP: Needed for calculations.

A pipette was used to measure a 25.0cm^3 volume of the diluted bleach and to transfer it into a conical flask. Solutions of potassium iodide, **KI**, and sulfuric acid were added.

The following reaction took place in the conical flask.

$$\mathbf{ClO^- + 2I^- + 2H^+ \quad Cl^- + I_2 + H_2O}$$

(a) Describe how the 25.0cm^3 sample of the original bleach solution was diluted to exactly 500cm^3. **(12)**

TIP: This question is worth 12 marks so you will need to give four relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

TIP: Will need dilution factor for calculation.

(b) (i) What colour developed when the potassium iodide and the sulfuric acid reacted with the diluted bleach in the conical flask? **(3)**

(ii) Give **two** reasons why **excess** potassium iodide was used. **(6)**

The solution in the conical flask was next titrated with a 0.10M solution of sodium thiosulfate (**$Na_2S_2O_3$**). The average volume of sodium thiosulfate required, when the procedure was repeated a number of times, was 16.1cm^3.

The balanced equation for the titration reaction was:

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

(c) What was the purpose of standing the conical flask on a white tile during the titrations? **(3)**

(d) (i) Name the indicator used in the titrations and (ii) state the colour change observed at the end point. **(6)**

(e) Calculate the concentration of **NaClO** in moles per litre in

(i) the diluted bleach,

(ii) the original bleach. **(12)**

(f) What was the concentration of **NaClO** in the original bleach

(i) in grams per litre,

(ii) as a % (w/v)? **(8)**

TIP: g/100cm^3

SOLUTION

1. (a)
- Pipette into 500cm^3 volumetric flask.
- Add deionised water until near mark.
- Add dropwise until bottom of meniscus is on the graduation mark and read at eye level.
- Stopper and invert several times. **(4 × 3)**

(b) (i) Brown. **(3)**

(ii) So that all the bleach has reacted. **(3)**

To keep the iodine in solution. **(3)**

(c) So that colour change is clearer. **(3)**

(d) (i) Starch. **(3)**

(ii) Blue to colourless. **(3)**

(e) (i) NaClO $\quad\quad$ $Na_2S_2O_3$

$V_{ox} = 25$ $\quad\quad$ $V_{red} = 16.1$

$M_{ox} = x$ $\quad\quad$ $M_{red} = 0.1$

$n_{ox} = 1$ $\quad\quad$ $n_{red} = 2$

$$\frac{V_{ox} \times M_{ox}}{n_{ox}} = \frac{V_{red} \times M_{red}}{n_{red}}$$

$$\frac{25 \times M_{ox}}{1} = \frac{16.1 \times 0.1}{2} \ \textbf{(6)}$$

$M_{ox} = 0.0322$ moles/L **(3)**

(ii) $0.0322 \times 20 = 0.644$ moles/L **(3)**

(f) (i) 0.644×74.5

$= 47.978$g/L **(3)**

TIP: Mass of NaClO.

(ii) $\frac{47.978}{10} = 4.7978$ (w/v) **(5)**

QUESTION 2

(a) Reflux is a widely used technique in organic chemistry.

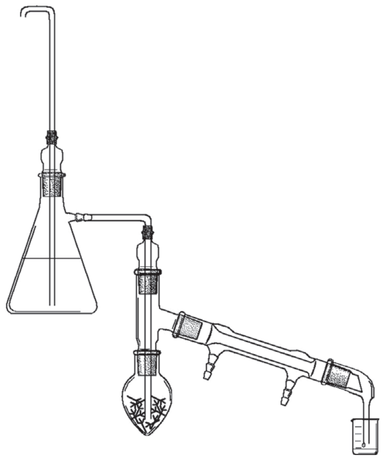
(i) Identify an experiment from your course where you refluxed a mixture.

(ii) Draw a fully labelled diagram of the reflux apparatus used in this experiment.

(iii) What happened to the liquid in the flask during reflux?

(iv) How did refluxing this mixture help bring the reaction to completion? **(30)**

(b) The diagram shows an apparatus suitable for steam distillation.



(i) What natural product did you extract in the school laboratory using steam distillation?

(ii) What was the appearance of the material collected during the steam distillation?

(iii) What substance distilled across along with the natural product?

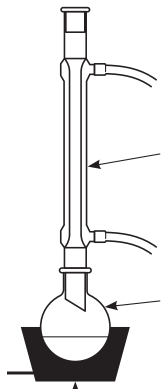
(iv) (1) Identify one safety feature of the apparatus drawn. (2) Explain how this feature contributes to the safe use of the apparatus. **(20)**

SOLUTION

2. (a) (i) Preparation of soap or preparation of ethanoic acid. **(6)**

(ii) Flask with contents shown or labelled.

- Anti-bumping granules.
- Condenser in correct position.
- Correct flow of water clearly indicated.
- Labelled or identifiable source of heat. **(4 × 3)**



(iii) Hot vapour rose, entered the condenser and dropped back into the flask. **(6)**

(iv) Allowed enough time to bring reaction to completion. **(6)**

(b) (i) Clove oil. **(5)**

(ii) Cloudy. **(6)**

(iii) Water. **(3)**

(iv) (1) Feature: Safety tube. **(3)**

(2) Explanation: Releases pressure. **(3)**

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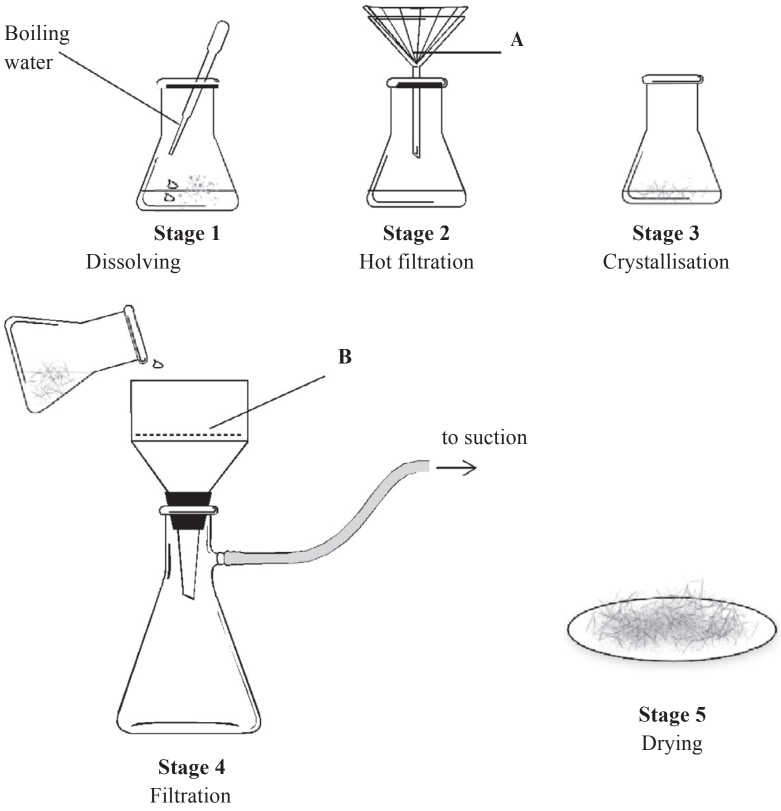
QUESTION 3

Organic solids are frequently purified by recrystallization.

An impure sample of benzoic acid contained small quantities of the two solids: salt (**NaCl**, white and soluble) and charcoal (**C**, black and insoluble).

The diagrams illustrate the five main stages in the recrystallization of the impure benzoic acid from water.



(a) What precaution should have been taken at Stage 1 to ensure the maximum yield of pure benzoic acid crystals at Stage 5? **(5)**

(b) What solid was collected (i) at **A**, (ii) at **B**? **(6)**

(c) Explain what should have been done at Stage 3 to ensure the maximum yield at Stage 5. **(6)**

(d) Comparing the solubilities of benzoic acid and salt (**NaCl**) in hot and in cold water, explain how benzoic acid is separated from the salt in this procedure. **(6)**

(e) Describe how the benzoic acid was dried at Stage 5. **(3)**

(f) (i) Describe with the aid of a labelled diagram how the melting points of the impure benzoic acid and of the recrystallized, dried benzoic acid could be measured.

(ii) How would you have expected the melting point values of the two samples to differ? **(18)**

(g) Give **one** common use of benzoic acid or of its salts. **(6)**

SOLUTION

3. **(a)** Dissolve crystals in minimum amount of hot water. **(5)**

(b) (i) Insoluble solid. **(3)**

(ii) Pure benzoic acid. **(3)**

(c) Place the flask in ice-water. **(6)**

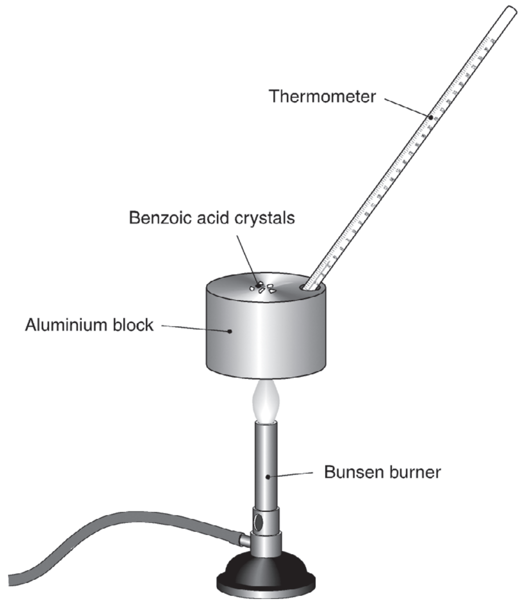
(d) Both substances soluble in hot water.
Benzoic much less soluble in cold water so comes out of solution. **(2 × 3)**

(e) Leave in a warm place. **(3)**

(f) (i) Place sample on melting block.
Place thermometer in melting block.
Heat block.
Note temperature range over which it melts. **(4 × 3)**

(ii) Impure sample melts at a lower temperature.
Impure sample has a less sharp melting point. **(2 × 3)**

(g) Used as a food preservative. **(6)**



SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

(a) Give **two** properties of cathode rays.

(b) State *Avogadro's law.*

(c) Give **two** possible shapes for a covalent molecule of general formula AB_2.

(d) Define *the mole*, the SI unit of chemical amount.

(e) When 4.10g of hydrated magnesium sulfate, $MgSO_4.xH_2O$, were heated strongly, 2.00g of anhydrous magnesium sulfate were obtained.

Calculate the value of **x**, the degree of hydration of the crystals.

(f) Complete and balance the equation for the chemical reaction that occurs when a piece of aluminium is placed in a solution of copper(II) ions: $Cu^{2+} + Al \rightarrow$

(g) Give **two** methods for removing all of the hardness in a water sample.

(h) Define the *activation energy* of a chemical reaction.

(i) What is a *homologous series* of organic compounds?

(j) What is the principle involved in the separation of a mixture by chromatography?

(k) Answer part **A** or part **B**.

A How do metallic crystals conduct electricity?

or

B What is meant by the *greenhouse factor* of a gas in the atmosphere?

SOLUTION

4. **(a)** Negatively charged **(3)**
and negligible mass. **(3)**

(b) Equal volumes of gases contain equal numbers of molecules **(3)**
under the same conditions of temperature and pressure. **(3)**

(c) Linear. **(3)**
V-shaped. **(3)**

(d) Amount containing as many particles as the number of atoms in 12g of carbon-12. **(6)**

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(e) $\frac{2.00}{2.10} = \frac{120}{18x}$

$36x = 252$ **(3)**

$x = 7$ **(3)**

(f) $3Cu^{2+} + 2Al \rightarrow 3Cu + 2Al^{3+}$

TIP: Formulas **(3)**, Balancing **(3)**.

(g) Distillation. **(3)**
Ion exchange resin. **(3)**

(h) Minimum energy required by colliding particles **(3)**
for effective collision to occur. **(3)**

(i) Same general formula.
Differ by CH_2.
Similar chemical properties.
Gradation in physical properties.
Similar method of preparation. **(Any 2 × 3)**

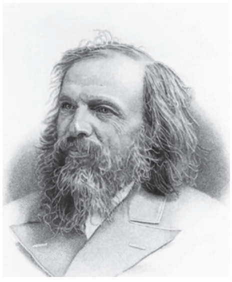
(j) Based on their different interactions **(3)**
with a stationary phase and a mobile phase. **(3)**

(k) **A:** The outer electrons
are free to move. **(2 × 3)**

B: Greenhouse effect relative
to carbon dioxide, which is given a value of 1. **(2 × 3)**

QUESTION 5

(a) Define (i) *atomic number*, (ii) *relative atomic mass*. **(11)**



(b) Sixty-two elements were known when Mendeleev, pictured on the right, published his periodic table of the elements in 1869.

(i) What was the basis (periodic law) used by Mendeleev in arranging the elements in his periodic table?

(ii) Why did Mendeleev leave spaces in his periodic table, e.g. where the element germanium occurs in the modern periodic table?

(iii) In a few instances Mendeleev reversed the order of elements required by his periodic law.

For example, he placed the element tellurium before the element iodine. Explain why he did this. **(12)**

(c) One of the most useful features of the periodic table of the elements is that it allows trends in the properties of the elements to be compared.

Explain why (i) the alkali metals are all reactive, (ii) the reactivity of the alkali metals increases down the group. **(9)**

(d) The arrangement of elements in the modern periodic table is now known to be consistent with their electrons filling into atomic orbitals of increasing energy.

(i) Define *atomic orbital*.

(ii) Write the electron configuration (*s*, *p*, etc.) of the element manganese (**Mn**).

(iii) What do the electron configurations of the series of elements from scandium to zinc have in common? **(18)**

SOLUTION

5. (a) (i) Number of protons in the nucleus of an atom of the element. **(5)**

(ii) Average mass of atom of element. **(3)**

Relative to $\frac{1}{12}$ mass of carbon-12 atom. **(3)**

(b) (i) When arranged in order of increasing atomic weight **(3)**
there is a periodic occurrence of similar elements. **(3)**

(ii) So that similar elements were in the same group. **(3)**

(iii) To fit the properties of the elements to groups. **(3)**

(c) (i) Readily lose a single electron. **(6)**

(ii) Increase in atomic radius so outer electron is further from nucleus. **(3)**

(d) (i) Region in space **(3)**
where there is a high probability of finding an electron. **(3)**

(ii) $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 3d^5$ **(6)**

(iii) Electrons occupy 3d sublevel. **(6)**

QUESTION 6

Over 20% of the crude oil refined at Whitegate in Cork Harbour in 2010 was imported from Libya. Libyan crude oil is particularly valued because of its rich light gasoline and naphtha content. Social unrest in the Middle East early in 2011 has again highlighted Ireland's heavy dependence on oil as an energy source. Unstable supplies, the high cost of importing quality crude oil, and environmental issues focus attention on alternative energy sources including fuels, other than fossil fuels, e.g. hydrogen, and diesel derived from vegetable oil.

(a) What is the nature of the chemicals that make up the bulk of crude oil? **(5)**

(b) Unprocessed crude oil, obtained by drilling on land or at sea, is not generally useful.

(i) Describe with the aid of a labelled diagram how crude oil is separated into useful substances in an oil refinery.

(ii) Give the major use for the light gasoline and naphtha fractions of crude oil. **(15)**

(c) (i) What is *catalytic cracking*? (ii) Why is it carried out in oil refining? **(9)**

(d) Hydrogen gas can be obtained industrially by the reaction between natural gas and water in the form of steam (steam reforming).

(i) Describe another method by which large quantities of hydrogen can be obtained from water.

(ii) State **one** disadvantage of using hydrogen as a fuel. **(9)**

(e) Steam reforming takes place according to the following balanced equation:

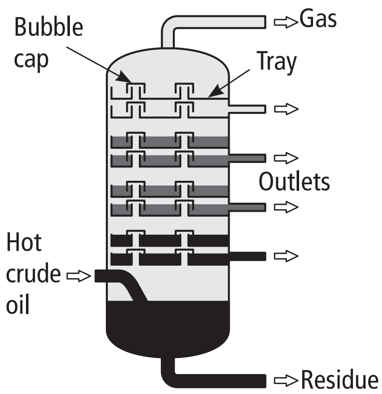
$$CH_{4\,(g)} + H_2O_{(g)} \rightarrow CO_{(g)} + 3H_{2\,(g)}$$

Calculate the heat of this steam reforming reaction given that the heats of formation of methane, steam and carbon monoxide are –74.6, –242 and –111 kJ mol^{-1} respectively. **(12)**

SOLUTION

6. (a) Hydrocarbons. **(5)**

(b) (i) Crude oil introduced at bottom of fractionating column.
Vapour moves up through the series of trays.
Fractions come off through outlets.
Depending on their boiling points. **(4 × 3)**



Fractionating column

(ii) Petrol. **(3)**

(c) (i) Splitting of long chain molecules
to give short chain molecules. **(2 × 3)**

(ii) To give more useful products. **(3)**

(d) (i) Electrolysis. **(6)**

(ii) Difficult to store and transport. **(3)**

(e)

CH_4	$\rightarrow$	$C + 2H_2$	ΔH	= 74.6 kJ **(3)**
$C + \frac{1}{2}O_2$	$\rightarrow$	CO	ΔH	= –111 kJ **(3)**
H_2O	$\rightarrow$	$H_2 + \frac{1}{2}O_2$	ΔH	= 242 kJ **(3)**
$CH_4 + 4H_2O$	$\rightarrow$	$CO + 3H_2$	ΔH	= 205.6 kJ **(3)**

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QUESTION 7

Sulfuric acid is a strong dibasic acid. The formula **HA** represents a weak monobasic acid.

(a) How do strong acids differ from weak acids in their behaviour in water according to (i) the Arrhenius theory, (ii) the Brønsted–Lowry theory? **(12)**

(b) (1) What is the conjugate base of (i) sulfuric acid, (ii) the weak acid **HA**?

(2) Which of these conjugate bases is the stronger? Explain. **(12)**

(c) Explain, by giving a balanced equation for its dissociation in water, that the conjugate base of sulfuric acid is itself an acid. **(6)**

(d) (i) Define pH. **(6)**

(ii) Calculate the pH of a 0.2M solution of a weak acid, **HA**, the value of whose acid dissociation constant, K_a, is 6.3×10^{-5}mol l^{-1}.

(iii) What is the concentration of a sulfuric acid solution that has the same pH? **(14)**

SOLUTION

7. (a) (i) Strong: Almost completely dissociated to give hydrogen ions (H^+) in solution. **(3)**
Weak: Only slightly dissociated to give hydrogen ions (H^+) in solution. **(3)**

(ii) Strong: Good proton donor. **(3)**
Weak: Poor proton donor. **(3)**

(b) (1) (i) Sulfuric acid: HSO_4^- **(3)**

(ii) HA: A^- **(3)**

(2) A^- – conjugate base of weak acid. **(2 x 3)**

(c) $HSO_4^- + H_2O \rightarrow SO_4^{2-} + H_3O^+$ **(6)**

(d) (i) $pH = -\log_{10} [H^+]$ **(6)**

(ii) $[H^+] = \sqrt{K_a \times M_a}$

$\sqrt{6.3 \times 10^{-5} \times 0.2}$ **(3)**

$= 0.0035$ **(3)**

$pH = -\log_{10}[H^+]$

$= -\log_{10}(0.0035)$

$= 2.45$ **(3)**

(iii) H^+ = inverse log (–2.45) **(3)**

$= 3.55 \times 10^{-3} \div 2 = 1.77 \times 10^{-3}$ **(2)**

QUESTION 8

Answer the questions below about methane (a saturated hydrocarbon), ethene (an unsaturated hydrocarbon) and benzene (an aromatic hydrocarbon).

(a) (i) Describe the mechanism of the monochlorination of methane. **(12)**

> **TIP:** Needs four relevant points worth 3 marks each or relevant diagrams. Use bullet points and put in as many points as you can remember.

(ii) State **three** pieces of experimental evidence for the mechanism you have given.

(iii) Explain how each piece of evidence supports the mechanism you have described. **(18)**

(b) Ethene can be made by passing ethanol vapour over hot aluminium oxide.

(i) Name the type of organic reaction involved in this conversion.

(ii) List the bonds broken and the bonds formed in this reaction. **(12)**

(c) Describe the bonding in benzene. **(8)**

SOLUTION

8. **(a)** (i)
- Initiation: Splitting of chlorine molecule (Cl_2) into free radicals by ultraviolet (UV) light.
- Propagation: Reaction of chlorine radical (Cl) with methane molecule (CH_4) giving hydrogen chloride and a methyl radical.
- Reaction of methyl radical with a chlorine molecule (Cl_2) to give monochloromethane and a chorine radical.
- Termination: Combination of remaining radicals to form molecules. **(4 × 3)**

(ii), (iii) (1) Promoted by UV at room temperature.
Does not take place in the dark at room temperature.

(2) Ethane formed.
Shows $CH_3^{\cdot}$ present.

(3) Add source of free radicals (e.g. tetramethyl lead).
Increased rate of reaction. **(3 × (2 × 3))**

(b) (i) Elimination. **(3)**

(ii) Broken: C–H and C–O

Formed: C=C and O–H **(6 + 3)**

(c) Six identical carbon-carbon sigma bonds.

Sigma bonds from carbon to hydrogen.

Delocalised pi electrons formed from 6 *p* orbitals. **(3 + 3 + 2)**

QUESTION 9

(a) Hydrogen iodide, when placed in a sealed vessel at 700K, decomposes to form hydrogen gas and iodine vapour. An equilibrium, described by the following balanced equation, is established.

$$2HI_{(g)} \rightleftharpoons H_{2\,(g)} + I_{2\,(g)} \quad \Delta H = 10.4\ kJ$$

(i) Write the equilibrium constant (K_c) expression for this reaction. **(5)**

(ii) Calculate the equilibrium concentration of hydrogen gas when 5 moles of hydrogen iodide decompose in a 12 litre vessel at 700K. The value of K_c at this temperature is 0.0185. **(18)**

(b) A pink solution was formed when crystalline cobalt(II) chloride, **$CoCl_2{\cdot}6H_2O$**, was dissolved in deionised water and the following equilibrium was established.

$$Co(H_2O)_6^{2+} + 4Cl^- \rightleftharpoons CoCl_4^{2-} + 6H_2O$$

pink blue

Concentrated hydrochloric acid was added carefully, dropwise, until the colour of the solution

changed to lilac (pale violet). A small volume of the lilac (pale violet) solution was placed in each of four test tubes labelled **A**–**D**. Test tube **D** was kept as a reference.

(1) Explain (i) the lilac (pale violet) colour in test tubes **A**–**D**,

(ii) the colour that appeared when a few drops of water were added to test tube **A**,

(iii) the colour that appeared when a few drops of concentrated hydrochloric acid were added to test tube **B**. **(18)**

(2) When test tube **C** was placed in a beaker containing ice and water the solution in the test tube became pink.

(i) Is the forward reaction exothermic or endothermic?

(ii) Justify your answer. **(9)**

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SOLUTION

9. (a) (i) $K_c = \frac{[H_2][I_2]}{[HI]^2}$ **(5)**

(ii)

	2HI	H_2	I_2
Initial	5	0	0
Change	$-2x$	$+1x$	$+1x$
At equilibrium	$5 - 2x$	x	x **(3)**

$\frac{(x) \times (x)}{(5 - 2x)^2} = 0.0185$ **(6)**

Getting the square root of both sides:

$x = 0.53$ **(6)**

Concentration in moles/L: $\frac{0.53}{12} = 0.044$ moles/L **(3)**

(b) (1) (i) Evidence of an equilibrium.
Shifted forward to decrease Cl^- concentration. **(3)**
According to Le Châtelier's principle. **(3)**

(ii) Pink. **(3)**
Shifted backward to decrease H_2O concentration. **(3)**

(iii) Blue. **(3)**
Shifted forward to decrease Cl^- concentration. **(3)**

(2) (i) Endothermic. **(3)**

(ii) Cooling always shifts the reaction in the exothermic direction. **(6)**

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) (i) Define the *rate of a chemical reaction*. **(5)**

There is a slow exothermic reaction between hydrogen and oxygen gases mixed in a 2:1 ratio at room temperature but the reaction becomes violently rapid if powdered platinum catalyst is added.

(ii) Suggest the type of catalysis responsible for the increased rate of reaction.

(iii) Describe the mechanism by which the powdered platinum increases the rate of reaction. **(12)**

TIP: Use bullet points and put in as many points as you can remember.

(iv) Draw a clearly labelled reaction profile diagram for the reaction with and without the catalyst. **(8)**

(b) Ethanol and carbon dioxide are obtained from glucose, $\mathbf{C_6H_{12}O_6}$, by the action of the enzyme zymase which occurs in yeast. (1) (i) Write a balanced chemical equation for this fermentation reaction. **(7)**

When a person drinks ethanol it is broken down in the liver at a fairly consistent average rate of 5.3g/hour in a woman and 7.3g/hour in a man. (ii) Name the primary metabolite of ethanol in the human liver. **(3)**

A woman drank two 175ml standard glasses of wine labelled 12.5% (v/v).

(2) (i) Calculate how long it took her liver to process all of the ethanol in the wine. Take the density of ethanol as 0.8g/ml.

(ii) Assuming that at no point was more than 90% of the consumed ethanol distributed in the woman's body fluids, state her maximum blood ethanol concentration in terms of mg ethanol/100ml blood. Take the woman's total body fluid volume as 28 litres and assume that the ethanol was distributed uniformly. **(15)**

(c) (1) What are *isotopes*? **(5)**

(2) Define (i) *radioactivity*, (ii) *radioisotope*. **(8)**

(3) Carbon-14 decays by beta particle emission.
Write a balanced equation to describe beta-decay of the carbon-14 nucleus. **(6)**

(4) The world's oldest shoe, found in a cave in Armenia, is pictured on the right.
In June 2010, having been radiocarbon dated, it was reported to be 5500 years old.
Explain why the carbon-12 to carbon-14 isotope ratio in the shoe leather changed over the 5500 years since the shoe was made. **(6)**

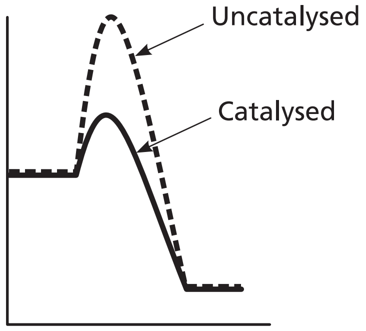
SOLUTION

10. (a) (i) Change in concentration per unit time of any one reactant or product. **(5)**

(ii) Heterogeneous catalysis. **(6)**

(iii)
- Reactants absorbed on surface of catalyst forming an activated complex.
- Higher concentration on surface gives a reaction.
- Desorption. **(6)**

(iv)



MARKS:
Reactants line higher than products line. **(3)**
Catalysed and uncatalysed curves correctly shown with either one correctly labelled. **(5)**

(b) (1) (i) $C_6H_{12}O_6 \rightarrow 2C_2H_5OH + 2CO_2$

TIP: Formulas **(4)**, Balancing **(3)**

(ii) Ethanal. **(3)**

(2) (i) 12.5% of 350ml = 43.75ml ethanol **(3)**
$43.75 \times 0.8 = 35$g **(3)**
$35 \div 5.3 = 6.6$ hours **(3)**

(ii) 90% of 35g = 31.5 ethanol **(3)**
31.5g in 28L = 112.5mg/100ml **(3)**

(c) (1) Atoms of same element having the same atomic number but different mass numbers due to the different numbers of neutrons in the nucleus. **(3 + 2)**

(2) (i) Spontaneous random decay of a nucleus to release α, β or γ radiation. **(3 + 2)**

(ii) Radioactive isotope. **(3)**

(3) ${}^{14}_{6}C \rightarrow {}^{0}_{-1}e + {}^{14}_{7}N$ **(2 × 3)**

(4) Carbon-14 decayed. **(6)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) What is meant by the *biochemical oxygen demand* (BOD) of a water sample? **(7)**

The BOD of a raw sewage sample was 350ppm and the BOD of the same sample after treatment was about 25ppm.

(i) Describe how the BOD was reduced by about 30% in primary sewage treatment. **(9)**

TIP: Use bullet points and put in as many points as you can remember.

(ii) Explain the processes by which the BOD was further reduced in secondary sewage treatment. **(9)**

TIP: Needs three relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

(b) (i) Distinguish between *ionic bonding and polar covalent bonding*. **(7)**

TIP: Give a definition of each.

(ii) Why do ionic substances conduct electricity when molten or dissolved in water but not in the solid state? **(6)**

(iii) Ammonia is polar covalent and is water-soluble.

(1) Show that the ammonia molecule (**NH_3**) has polar covalent bonding.

(2) Describe the processes involved when ammonia dissolves in water. **(12)**

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

A

Roy Plunkett, pictured on the right, produced the polymer poly(tetrafluoroethene) (Teflon) accidentally in 1938 when he was researching refrigerants.

(i) Identify the monomer used to manufacture poly(tetrafluoroethene) (Teflon). **(4)**

(ii) What type of polymerisation reaction occurs in the manufacture of poly(tetrafluoroethene) (Teflon)? **(3)**

(iii) Draw two repeating units of the Teflon polymer. **(6)**

(iv) Give **two** properties of poly(tetrafluoroethene) (Teflon). In the case of each property you have stated, give a major use of the polymer that makes use of that property. **(12)**

or

B

Outline the chemical processes that give rise to the occurrence of ozone gas in the stratosphere.

Why is ozone gas not produced in this way in the lower atmosphere? **(10)**

The destruction of the ozone layer is a matter of environmental concern. A non-metal oxide and chlorine atoms from CFCs are considered to be mainly responsible for the destruction of ozone.

(i) What are CFC molecules? **(3)**

(ii) Why do CFC molecules have long residence times in the lower atmosphere? **(3)**

(iii) Give a major use of CFCs before their production was restricted in 1987. **(3)**

(iv) Name the non-metallic oxide that is associated with ozone destruction in the stratosphere. **(3)**

Give a source of this oxide. **(3)**

SOLUTION

11. (a) ppm (mgl^{-1}) of oxygen consumed
when sample kept in the dark for 5 days at 20°C. **(4 + 3)**

(i) Removal of solids
by screening and settlement. **(6 + 3)**

(ii)
- Biological.
- Aerobic.
- Decomposition of waste using activated sludge process. **(3 × 3)**

(b) (i) Ionic: Force of attraction between oppositely charged ions.
Polar: Unequal sharing of bonding electrons. **(4 + 3)**

(ii) Molten: Ions free to move. **(3)**
Solid: Ions not free to move. **(3)**

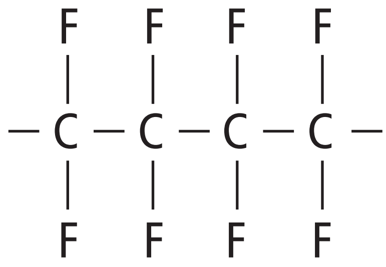
(iii) (1) There is an electronegativity difference between N and H. **(3)**
N has a greater attraction for electrons. **(3)**

(2) Hydrogen bonds between slightly negative O of water and H of ammonia **(3)**
and between slightly positive H of water and N of ammonia. **(3)**

(c) **A** (i) Tetrafluoroethene. **(4)**

(ii) Addition. **(3)**

(iii)



(6)

(iv) Temperature tolerant.
Used in cooking utensils.

Corrosion resistant.
Used in containers. **(4 × 3)**

B Decomposition of oxygen molecule into oxygen atoms (radicals) by UV light.
Oxygen atom reacts with oxygen molecule forming ozone. **(4 + 3)**
Lack of UV light. **(3)**

(i) Chlorofluorocarbons. **(3)**

(ii) They are stable and unreactive. **(3)**

(iii) Refrigerants. **(3)**

(iv) Nitrogen(II) oxide. **(3)**

Lightning. **(3)**

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SECTION A

Answer at least two questions from this section.

QUESTION 1

The total hardness values of a water supply before and after it had been passed through a laboratory deioniser were compared. This was done by adding a suitable indicator and a small volume of buffer solution to 50.0cm^3 samples of the water in a conical flask and titrating with **edta** solution.

The reaction between the calcium ions and the magnesium ions (represented by M^{2+}) in the water and the edta (represented by H_2Y^{2-}) is given in the following balanced equation.

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

(a) What is the full name of the **edta** reagent? **(5)**

(b) (i) Name an indicator suitable for this titration and (ii) state the colour change observed at the end point of the titration. **(9)**

(c) (i) What is the general purpose of buffer solutions?

(ii) What buffer was required for this titration?

(iii) What problem would have been encountered in this titration if the wrong buffer were used? **(9)**

(d) Explain the two operations, involving the titration flask and its contents, carried out as the edta was being added from the burette during the titrations. **(6)**

(e) It was found that 50.0cm^3 samples of the hard water before ion exchange required an average of 9.20cm^3 of 0.01M edta solution for complete reaction and that 50.0cm^3 samples of the water after ion exchange required an average of 2.40cm^3 of the same edta solution for complete reaction.

Calculate the total hardness of the water before ion exchange in

(i) moles per litre of calcium and magnesium ions (**M^{2+}**),

(ii) grams per litre expressed in terms of $CaCO_3$,

(iii) ppm in terms of $CaCO_3$.

Repeat these calculations for the water after ion-exchange. **(15)**

(f) (i) State and (ii) explain whether the water having passed through the deioniser is suitable for use as deionised water in the laboratory or if the deioniser needs to be changed or regenerated. **(6)**

TIP: Need a separate statement and explanation to achieve 2 × 3 marks.

SOLUTION

1. (a) (i) Ethylenediamine. **(3)**

(ii) Tetraacetic acid. **(2)**

(b) Eroichrome Black T. **(3)**
Wine red **(3)**
to blue. **(3)**

TIP: Need to give both colours.

(c) (i) To stabilise the pH of a solution. **(3)**

(ii) pH 10. **(3)**

(iii) If the wrong buffer were used, an inaccurate end point would occur. **(3)**

(d) Swirl to mix.
Allow time after addition from burette for reaction.
Wash down sides with deionised water.
On white surface. **(Any 2 × 3)**

(e) **Water** **edta**

$V_{Ca} = 50$ $V_{edta} = 9.2$

$M_{Ca} = ?$ $M_{edta} = 0.01$

$n_{Ca} = 1$ $n_{edta} = 1$

(i) $\frac{V_{Ca}M_{Ca}}{n_{ca}} = \frac{V_{edta}M_{edta}}{n_{edta}}$

$\frac{50 \times M}{1} = \frac{9.2 \times 0.01}{1}$ **(3)**

$= 1.84 \times 10^{-3}\ M$ **(3)**

(ii) $1.84 \times 10^{-3} \times 100 = 0.184$ moles/L **(3)**

(iii) $0.184 \times 1000 = 184$ **(3)**

Water **edta**

$V_{Ca} = 50$ $V_{edta} = 2.4$

$M_{Ca} = ?$ $M_{edta} = 0.01$

$n_{Ca} = 1$ $n_{edta} = 1$

$\frac{50 \times M}{1} = \frac{2.40 \times 0.01}{1}$

$= 4.8 \times 10^{-4}\ M$

$4.8 \times 10^{-4} \times 100 = 0.048$ moles/L

$0.048 \times 1000 = 48$ **(3)**

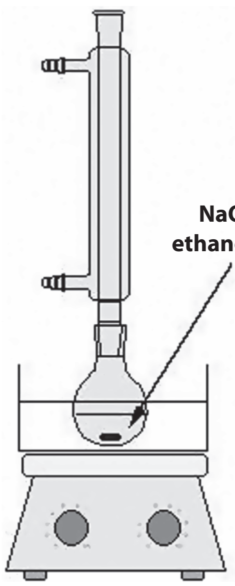
(f) The water is unsuitable because hardness remains after passing through the deioniser. **(3)**
The deioniser needs to be replaced. **(3)**

QUESTION 2

To prepare soap, a student refluxed 8.9g of glyceryl tristearate (obtained from animal fat), 2g of sodium hydroxide pellets and 30cm^3 of ethanol, together with a few anti-bumping granules, using the apparatus shown on the right. At the end of the experiment 7.0g of pure, dry soap were isolated. The balanced equation for the reaction is as follows:

$$\begin{array}{l} C_{17}H_{35}COOCH_2 \\ \quad | \\ C_{17}H_{35}COOCH + 3NaOH \longrightarrow 3C_{17}H_{35}COONa + \begin{array}{l} HOCH_2 \\ | \\ HOCH \\ | \\ HOCH_2 \end{array} \\ \quad | \\ C_{17}H_{35}COOCH_2 \end{array}$$

glyceryl tristearate — sodium stearate — glycerol



(a) Write the systematic (IUPAC) name for glycerol. **(5)**

(b) (i) Why was the reaction mixture heated under reflux?

(ii) Name the type of reaction that occurred during the reflux.

(iii) What was the purpose of the ethanol? **(12)**

(c) (i) Describe, with the aid of labelled diagrams, how the ethanol was removed after the reflux stage.

(ii) How was the soap isolated from the other substances left in the reaction mixture?

(iii) After isolating the soap, how was it purified and dried? **(21)**

(d) Given that the sodium hydroxide was in excess, calculate the percentage yield of soap (sodium stearate). **(12)**

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SOLUTION

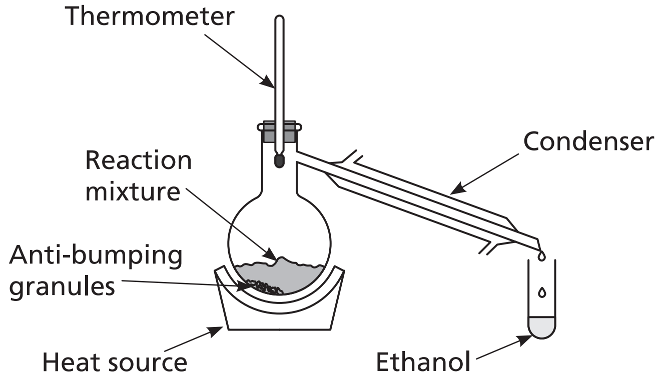
2. **(a)** Propane–1, 2, 3–triol. **(5)**

(b) (i) To bring reaction to completion without loss of ethanol. **(6)**

(ii) Saponification. **(3)**

(iii) Solvent. **(3)**

(c) (i)



(6)

(ii) Reaction mixture added to brine. **(3)**
Precipitated soap got by filtration. **(3)**

(iii) Wash with brine **(6)**
and place in a warm place. **(3)**

(d) $\frac{8.9}{890} = 0.01$ moles of glyceryl tristearate. **(3)**

Ratio of glyceryl tristearate to soap is 1:3.

$0.01 \times 3 = 0.03$ moles of soap. **(3)**

$0.03 \times 306 = 9.18$g (theoretical yield). **(3)**

Percentage yield $= \frac{\text{Actual yield}}{\text{Theoretical yield}} \times 100$

$\frac{7}{9.18} \times 100 = 76\%$ **(3)**

QUESTION 3

A stopwatch was started when 50cm^3 of a 0.20M sodium thiosulfate solution was poured into a conical flask containing 10cm^3 of 1.0M HCl solution. The conical flask was put standing on top of a black cross marked on white paper. The time for the cross to become obscured by the precipitate produced in the reaction was measured. The reciprocal of this reaction time (1/*t*) was taken as a measure of the initial rate of the chemical reaction.

The stock 0.20M solution of sodium thiosulfate was then diluted with deionised water to produce 50cm^3 each of 0.16M, 0.12M, 0.08M, 0.04M and 0.02M solutions in turn. The times taken for these solutions to react with 10cm^3 of the 1.0M HCl solution were also measured in identical conical flasks as described above. All six reactions were carried out at 20°C and the results are given in the table.

Concentration $Na_2S_2O_3$ (M)	0.20	0.16	0.12	0.08	0.04	0.02
Reaction time (min)	1.14	1.43	1.89	2.94	5.88	11.11
1/*t* (min^{-1})	0.88	0.70	0.53	0.34	0.17	0.09

(a) Identify the precipitate produced in each flask. **(5)**

(b) Describe a procedure for diluting the 0.20M sodium thiosulfate solution to give 50cm^3 of a 0.12M solution. **(9)**

TIP: Three relevant points are required for 9 marks. Use bullet points, making as many points as you can.

(c) Why are the concentration and the volume of the HCl solution kept constant? **(6)**

(d) (i) Plot a graph of reaction rate (1/*t*) *versus* concentration of sodium thiosulfate.

(ii) What conclusion can be drawn from the graph about the relationship between the rate of the reaction and the concentration of the sodium thiosulfate? **(18)**

(e) Use your graph to predict the time taken for $50cm^3$ of a 0.10M solution of sodium thiosulfate to react with $10cm^3$ of the 1.0M HCl solution at 20°C. **(6)**

(f) The procedure described above was repeated using $50cm^3$ portions of the 0.20M sodium thiosulfate solution and $10cm^3$ portions of the 1.0M HCl solution at a number of different temperatures between 10°C and 70°C and the reaction times were measured as before.

(i) Would you expect the reaction times to increase, decrease, or stay the same, as the temperature was increased?

TIP: Note that you are asked for reaction **time** not reaction **rate**.

(ii) Justify your answer. **(6)**

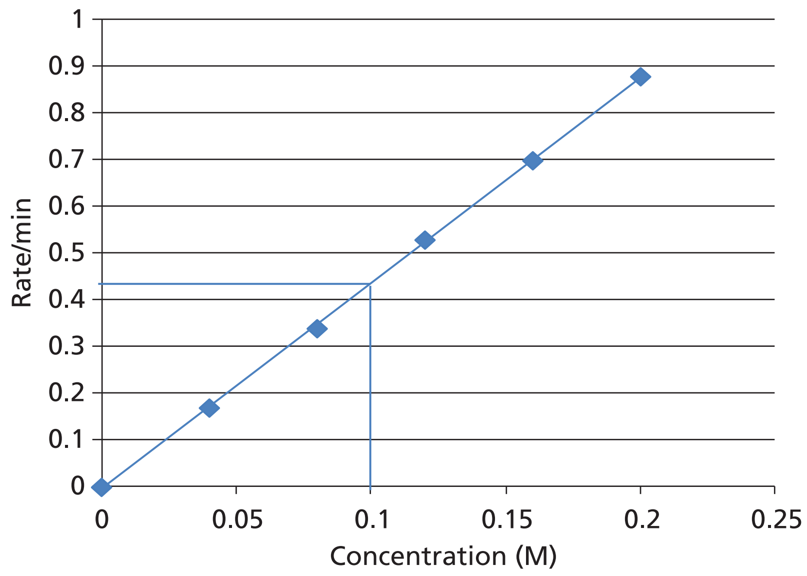
SOLUTION

3. (a) Sulfur. **(5)**

(b)
- Measure $30cm^3$ of the 0.20M thiosulfate solution. **(3)**
- Dilute to $50cm^3$. **(3)**
- Using deionised water. **(3)**

(c) So that only one variable is changed. **(6)**

(d) (i)



MARKS:

Correctly labelled. **(3)**
Scaled axes. **(3)**
All points plotted. **(3)**
Straight line drawn. **(3)**

(ii) Straight-line graph indicating rate is directly proportional to the concentration. **(6)**

(e) Time $= \frac{1}{\text{rate}} = \frac{1}{0.43} = 2.32$ mins. **(6)**

(f) (i) Reaction time would decrease. **(3)**

(ii) Reaction rate increases with temperature. **(3)**

SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

(a) Write the electron configuration (*s, p, etc.*) of the oxygen (oxide) ion (**O^{2-}**).

(b) State **two** differences between Mendeleev's periodic table and the modern periodic table of the elements.

(c) What are the **two** possible shapes of molecules of general formula **QX_2**?

(d) How many atoms of iron are there in a 30g bowl of cornflakes that contains 0.0024g iron per 30g serving?

(e) State *Gay-Lussac's law of combining volumes*.

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(f) Define *activation energy*.

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

(h) What is an *ideal gas*?

TIP: Definition.

(i) What happens during the secondary stage of sewage treatment?

(j) Draw the structural formulae of any two molecules with the molecular formula $C_3H_6O_2$.

(k) Answer part **A** or part **B**.

A Write a balanced equation for the reduction of iron(III) oxide by carbon monoxide in a blast furnace.

or

B Write a balanced equation for the reaction that occurs when sulfur dioxide from industrial gaseous emissions dissolves in water.

SOLUTION

4. (a) $1s^2, 2s^2, 2p^6$ **(6)**

(b) Arranged in terms of atomic weight.
Reversed some pairs of elements.
Left gaps for undiscovered elements.
Did not put transition elements in separate block. **(Any 2 × 3)**

(c) Linear. **(3)**
V-shaped. **(3)**

(d) $\frac{0.0024}{56} = 4.29 \times 10^{-5}$ moles of iron. **(3)**
$4.29 \times 10^{-5} \times 6 \times 10^{23} = 2.6 \times 10^{19}$ atoms. **(3)**

(e) The volumes of reacting gases and their gaseous products **(3)** are in small whole number ratios. **(3)**

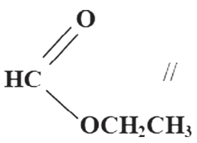
(f) Minimum energy required by colliding particles **(3)** for a collision to occur. **(3)**

(g) Sigma involves end-on overlap of orbitals. **(3)**
Pi involves side-on (sideways) overlap of p-orbitals. **(3)**

(h) A gas that obeys the gas laws **(3)** under all conditions of temperature and pressure. **(3)**

(i) Biological. **(3)**
Oxidation of sewage. **(3)**

(j)



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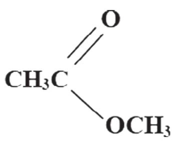


(2 × 3)

(k) **A:** $Fe_2O_3 + 3CO \longrightarrow 2Fe + 3CO_2$
B: $SO_2 + H_2O \longrightarrow H_2SO_3$ **(6)**

TIP: Formulas **(3)**, Balancing **(3)**.

QUESTION 5

(a) State **two** assumptions of Dalton's atomic theory of 1808. **(8)**

(b) The electron was the first of the sub-atomic particles to be discovered. It was identified in experiments using cathode rays that were carried out in the late nineteenth century.

Name the scientist

(i) who, about 1897, measured the ratio of charge to mass of the electron, *e*/*m*,

(ii) who, about 1910, proved that the electrons in an atom reside in an electron cloud surrounding a small dense positive central nucleus,

(iii) who, about 1911, measured the charge on the electron, *e*. **(9)**

(c) The arrangement of the electrons in the electron cloud proposed in 1913 by Bohr, pictured on the right, was consistent with the hydrogen emission spectrum.
Outline Bohr's atomic theory based on the hydrogen emission spectrum. **(15)**

TIP: Use bullet points and make as many points as you can.

(d) State **two** limitations of Bohr's theory that led to its modification. **(6)**

(e) (i) Define *atomic orbital*.

(ii) Draw the shape of the *p*-orbital.

(iii) State the maximum number of electrons that can be accommodated in a *p*-orbital. **(12)**

SOLUTION

5. (a) Small.
Indivisible.
Identical atomic mass for a particular element. **(Any 2 × 4)**

(b) Thomson. **(3)**
Rutherford. **(3)**
Millikan. **(3)**

(c)
- The electron in a hydrogen atom occupies fixed energy levels.
- An electron in an energy level does not radiate energy.
- Electron occupies lowest energy levels available.
- The electron can move to a higher energy level if it receives an amount of energy.
- The electron in an excited state (higher level) is unstable.
- The excited electron falls back to a lower energy level.
- Emitting the excess energy in the form of a photon of light (*hf*). **(Any 4: (6 + 3 × 3))**

(d) Did not work for higher elements. **(3)**
Did not take wave–particle duality into account. **(3)**

(e) (i) Region around the nucleus of an atom **(3)**
where there is a high probability of finding an electron. **(3)**

(ii)

(3)

(iii) (2) **(3)**

QUESTION 6

(a) Give the systematic (IUPAC) names for the three hydrocarbon compounds **X**, **Y** and **Z**. **(8)**

TIP: You need to give full correct names.

(b) Compounds **X** and **Z** are obtained from the same fraction in the oil refining process.

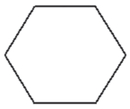
(i) Name the fraction in which **X** and **Z** occur.

(ii) What **two** properties of the compounds are responsible for them being found in the same fraction? **(9)**

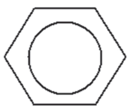
(c) (i) What is meant by *auto-ignition* in petrol engines?
Compound **Y** has an octane number of 83 and therefore has the same octane rating as an 83:17 mixture of two reference hydrocarbons.

(ii) Name the reference hydrocarbon that is the major component of the 83:17 reference mixture. **(6)**

$CH_3(CH_2)_5CH_3$ **X**



Y



$-CH_3$ **Z**

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(d) (i) Define *heat of combustion*.

(ii) Outline how the heat of combustion of **X** could be measured using a bomb calorimeter. **(15)**

(e) In order to increase its octane rating, compound **X** is converted to compound **Z** in oil refineries by the following reforming (dehydrocyclisation) process:

$$C_7H_{16\,(l)} \rightarrow C_7H_{8\,(l)} + 4H_{2\,(g)}$$

(i) Calculate the heat change for this reaction given that the heats of formation of $C_7H_{16\,(l)}$, and $C_7H_{8\,(l)}$ are –224.2 and 12.4kJ mol^{-1}, respectively.

(ii) State **one** important industrial use for the hydrogen produced in this reaction. **(12)**

SOLUTION

6. (a) X = Heptane.
Y = Cyclohexane.
Z = Methylbenzene. **(2 × 3 + 2)**

(b) (i) Naphtha. **(3)**

(ii) Similar carbon number. **(3)**
Similar boiling points. **(3)**

(c) (i) Tendency to undergo knocking. **(3)**

(ii) 2,2,4-trimethylpentane. **(3)**

(d) (i) Energy released when one mole of a substance is completely burned **(3)** in excess oxygen. **(3)**

(ii) Place known amount of substance in a bomb calorimeter.
Pressurise with oxygen.
Place bomb in known quantity of water.
Ignite electrically.
Find heat produced using the rise in temperature and the heat capacity of the system.
From this calculate the heat produced for one mole of the substance. **(Any 3 × 3)**

(e) (i)

$C_7H_{16} \rightarrow 7C + 8H_2$	$\Delta H = 224.2$	kJ mol^{-1} **(3)**
$7C + 4H_2 \rightarrow C_7H_8$	$\Delta H = 12.4$	kJ mol^{-1} **(3)**
$C_7H_{16} \rightarrow C_7H_8 + 4H_2$	$\Delta H = 236.6$	kJ mol^{-1} **(3)**

(ii) Hydrogen used as a fuel. **(3)**

QUESTION 7

Phosphorus(V) chloride decomposes into phosphorus(III) chloride and chlorine at a temperature of 500K according to the following balanced equation.

$$PCl_{5\,(g)} \rightleftharpoons PCl_{3\,(g)} + Cl_{2\,(g)}$$

(a) This is a reversible reaction and a dynamic equilibrium is reached.

(i) Explain the underlined terms.

(ii) Why is the equilibrium described as *dynamic*? **(11)**

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

(ii) Write the equilibrium constant (K_c) expression for the above reaction. **(12)**

(c) When 208.50g of phosphorus(V) chloride is heated in a 100 litre container at a temperature of 500K equilibrium is established with 53.25g of chlorine gas present in the container.

Calculate the value of the equilibrium constant (K_c) for the reaction at 500K. **(12)**

(d) When the temperature of the equilibrium mixture is increased, the phosphorus(V) chloride decomposes further.

(i) Is the reaction endothermic or exothermic?

(ii) Justify your answer. **(6)**

(e) (i) What change, if any, would an increase in pressure have on the value of K_c?

(ii) Explain. **(9)**

SOLUTION

7. **(a)** (i) Reversible reaction: Reaction is going in both directions. **(4)**
Equilibrium: Rate of forward reaction equals rate of reverse reaction. **(4)**

(ii) Reactants producing products and products producing the reactants simultaneously. **(3)**

(b) (i) If a system at equilibrium is disturbed **(3)**
it tends to minimise the disturbance. **(3)**

(ii) $K_c = \frac{[PCl_3]\,.\,[Cl_2]}{[PCl_5]}$ **(6)**

TIP: Square brackets are necessary.

(c)

	PCl_5	PCl_3	Cl_2
Initial	1	0	0 **(3)**
Change	$-1x$	$+1x$	$+1x$ **(3)**
At equilibrium (100L)	0.25	0.75	0.75
At equilibrium (L)	0.0025	0.0075	0.0075 **(3)**

$\frac{(0.0075)\times(0.0075)}{0.0025} = 0.0225$ **(3)**

(d) (i) The reaction is endothermic. **(3)**

(ii) System responds to absorb the added heat. **(3)**

(e) (i) K_c will not change. **(3)**

(ii) The value of K_c is constant at constant temperature. **(6)**

QUESTION 8

(a) Define (i) acid, (ii) conjugate acid, according to the Brønsted–Lowry theory. **(8)**
In acting as an acid–base indicator methyl orange behaves like a weak acid. Letting **HX** represent methyl orange, it dissociates as follows:

$$HX \rightleftharpoons H^+ + X^-$$

In aqueous solution, the undissociated form (**HX**) is red and the dissociated form (X^-) is yellow.

(iii) Distinguish between a strong acid and a weak acid. **(6)**

TIP: A definition of both is sufficient for full marks.

(iv) What is the conjugate base of **HX**?

(b) (i) State and (ii) explain the colour observed when a few drops of the methyl orange solution is added to (i) a 0.1M solution of **HCl**, (ii) a 0.1M solution of **NaOH**. **(12)**

(c) Calculate the pH of (i) a 0.1M solution of **NaOH**, (ii) a 0.004M solution of methyl orange, if methyl orange has a K_a value of 3.5×10^{-4}. **(9)**

(iii) Draw a clearly labelled diagram of the pH curve you would expect to obtain when 50cm^3 of 0.1M **NaOH** solution is added slowly to 25cm^3 of a 0.1M **HCl** solution.

(iv) Explain by referring to the curve why almost any acid–base indicator can be used in this titration. **(12)**

SOLUTION

8. **(a)** (i) Proton (H^+) donor. **(4)**

(ii) A base with a proton added. **(4)**

(iii) Strong acid: Good proton donor. **(3)**
Weak acid: Poor proton donor. **(3)**

(iv) X^- **(3)**

(b) (i) Red colour observed. **(3)**

(ii) Equilibrium shifted to the left by H^+ present. **(3)**
Yellow colour observed. **(3)**
Equilibrium shifted to the right by OH^- removing H^+. **(3)**

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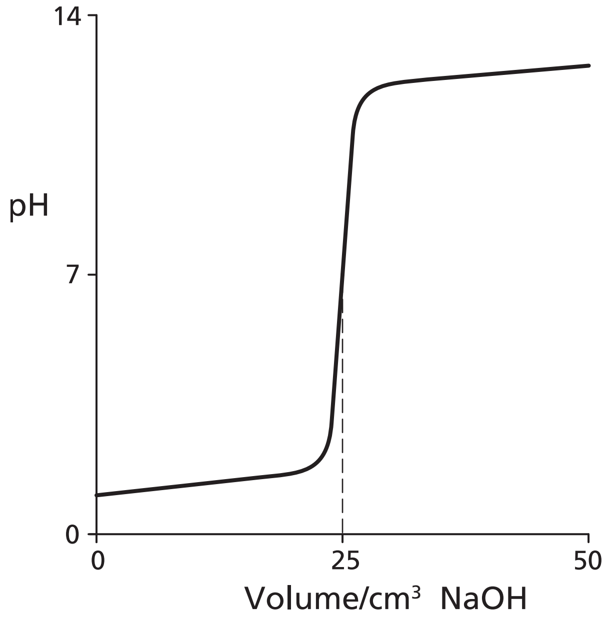
(c) (i) $pOH = -\log_{10} [OH^-]$
$-\log_{10} 0.1 = 1$ **(2)**
$14 - 1 = 13$ **(1)**

(ii) $[H^+] = \sqrt{K_a \times M_a}$
$\sqrt{3.5 \times 10^{-4} \times 0.004}$
$= 0.00118$ **(3)**
$pH = -\log_{10} [H^+]$
$= -\log_{10} (0.00118)$
$= 2.9$ **(3)**

(iii)

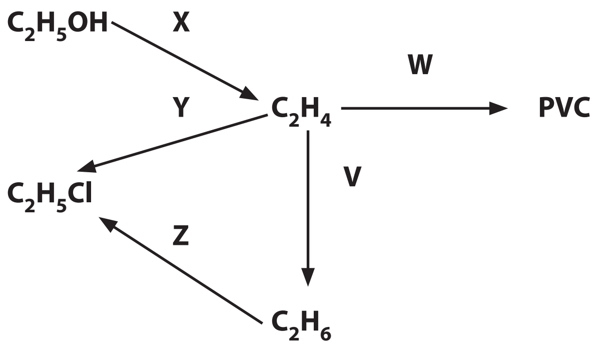


MARKS:
Axes labelled correctly. **(3)**
Correct shaped curve. **(3)**
pH jump around 25cm^3. **(3)**

(iv) As the range of most indicators is within the pH jump on the graph. **(3)**

QUESTION 9

Study the reaction scheme and answer the questions that follow.



(a) Name the molecule in the scheme that contains no tetrahedral carbon atoms. **(5)**

(b) Identify (i) an addition reaction, (ii) a substitution reaction, in the scheme above. **(6)**

(c) Describe the mechanism of reaction **Y**. **(12)**

TIP: Use bullet points and make as many points as you can **(4 × 3)**. Mechanism diagrams are also acceptable.

(d) State the reagent(s) and condition(s) required to bring about (i) conversion **V**, (ii) conversion **Z**. **(12)**

(e) Draw a labelled diagram to show how conversion **X** could be carried out in the school laboratory. **(9)**

(f) Conversion **W** involves a three-step synthesis. Draw the structures of the two organic intermediates in this synthesis. **(6)**

SOLUTION

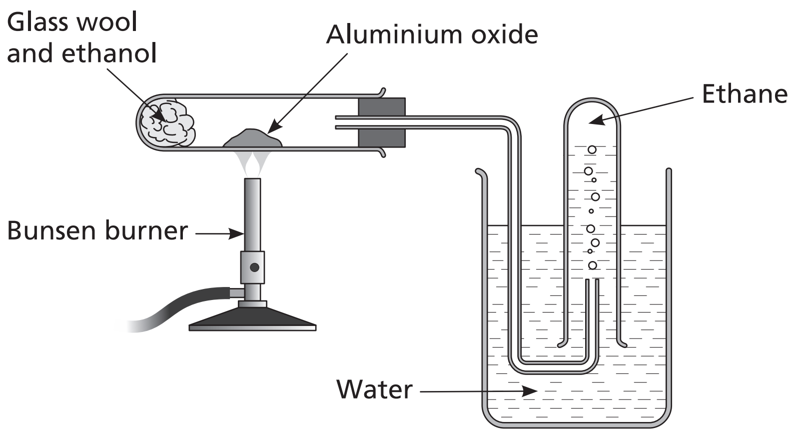
9. (a) Ethene. **(5)**

(b) (i) Y or V **(3)**
(ii) Z **(3)**

(c)
- Heterolytic fission of hydrogen chloride molecule. **(3)**
- Addition of H^+ to the double bond. **(3)**
- Forming carbonium ion. **(3)**
- Addition of Cl^- to the carbonium ion to give chloroethane. **(3)**

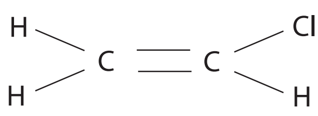
(d) (i) H_2 **(6)**
(ii) Cl_2 **(3)**
UV light. **(3)**

(e)

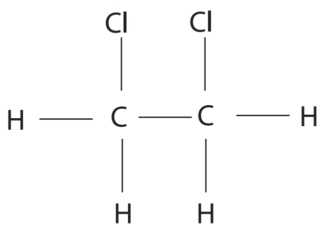


MARKS:
Apparatus correctly drawn. **(3)**
Ethanol held in glass wool. **(3)**
Aluminium oxide correctly placed and heated. **(3)**

(f)



(3)



(3)

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) (i) Define *electronegativity*. **(6)**

(ii) State **two** factors that cause electronegativity values to increase across a period in the periodic table of the elements. **(6)**

(iii) State which of the following compounds contain intermolecular hydrogen bonds:
(i) hydrogen chloride, **HCl**, (ii) water, $\mathbf{H_2O}$, (iii) ammonia, $\mathbf{NH_3}$.

(iv) Justify your answer. **(9)**

(v) Suggest a reason why the boiling point of ammonia (–33°C) is significantly lower than that of water (100°C). **(4)**

(b) A chemist synthesised benzoic acid in the laboratory and purified it by recrystallisation. The melting point of the product was measured before and after recrystallisation.

(i) Describe with the aid of a labelled diagram how the melting point of either the crude product or the recrystallised product could have been measured. **(12)**

(ii) Give **two** ways the chemist could have concluded from the melting point measurements that the recrystallised product was purer than the material first prepared. **(6)**

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(iii) Name the instrumental technique that could have been used to confirm the identity of the product based on its absorbtion of a unique set of low energy electromagnetic radiations. **(3)**

(iv) Give **one** important use of benzoic acid or its salts. **(4)**

(c) The balanced equation for the oxidation of ethanol to ethanal using sodium dichromate in acidic conditions is as follows:

$$3C_2H_5OH + Na_2Cr_2O_7 + 4H_2SO_4 \rightarrow 3CH_3CHO + Cr_2(SO_4)_3 + Na_2SO_4 + 7H_2O$$

(i) Deduce the oxidation numbers of chromium in the sodium dichromate reagent and in the chromium sulfate product. **(7)**

(ii) State the colour change observed as this reaction proceeds. **(3)**

(iii) Describe a test you could carry out to confirm that the organic product is an aldehyde. **(9)**

(iv) Give the name and structure of another organic compound that could be formed when ethanol is oxidised using acidified sodium dichromate. **(6)**

SOLUTION

10. (a) (i) Relative attraction **(3)**
that an atom of an element has for a shared pair of electrons of electrons in a covalent bond. **(3)**

(ii) Increasing effective nuclear charge. **(3)**
Decreasing atomic radius. **(3)**

(iii) H_2O **(3)**
NH_3 **(3)**

(iv) In both of these molecules hydrogen is bonded to a small highly electronegative element. **(3)**

(v) Weaker, less effective hydrogen bonding in ammonia. **(4)**

(b) (i) Place a sample on heating block.
Place thermometer in melting block.
As the block is heated
note temperature range over which the sample melts. **(6 + 2 × 3)**

(ii) Melting point closer to correct value. **(3)**
Sharper melting point. **(3)**

(iii) Infra-red (IR) spectroscopy. **(3)**

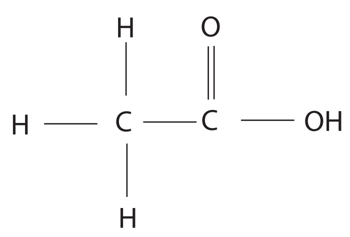
(iv) Food preservative. **(4)**

(c) (i) +6 to +3 **(4 + 3)**

(ii) Orange to green. **(3)**

(iii) Heat with **(3)**
Fehling's solution. **(3)**
Brick-red precipitate results. **(3)**

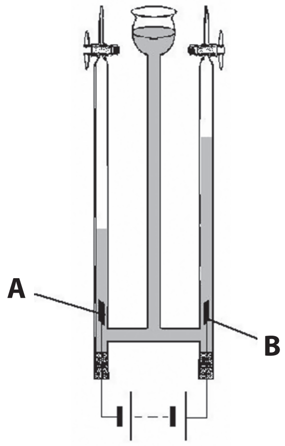
(iv) Ethanoic acid. **(3)**



(3)

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**



(a) The apparatus shown on the right was used to investigate the electrolysis of aqueous sodium sulfate to which a few drops of universal indicator solution had been added. The solution was initially pale green in colour.

(i) Name a material suitable for use as the electrodes **A** and **B**. **(4)**

(ii) How was the current conducted through the electrolyte? **(3)**

(iii) (1) At which electrode, **A** or **B**, did oxidation occur?

(2) Write the equation for the reaction that occurred at this electrode. **(9)**

(iv) When a current passed through the electrolyte for 15 minutes, 8.5cm^3 of gas was collected above the positive electrode. What volume of gas was collected above the negative electrode in the same time? **(3)**

(v) (1) At which electrode did a blue colour appear? (2) Justify your answer. **(6)**

(b) Define (i) *radioactivity*, (ii) the *half-life* of a radioactive isotope. **(10)**

Americium–241 is a radioactive isotope used in domestic smoke detectors. Americium–241 has a half-life of 432 years and decays by emitting alpha particles to produce neptunium.

(iii) Determine the value of *A* and the value of *Z* in the following nuclear equation for the alpha decay of an americium–241 nucleus. **(6)**

$$^{241}_{95}\mathbf{Am} \rightarrow\ ^{A}_{Z}\mathbf{Np} +\ ^{4}_{2}\mathbf{He} + \mathbf{energy}$$

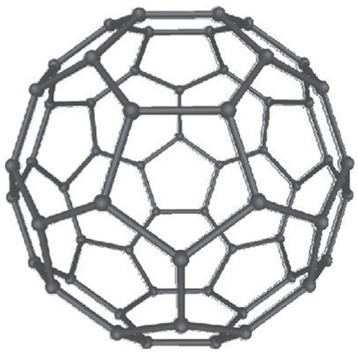
(iv) Alpha particles are hazardous to human health. State one risk associated with exposure to alpha radiation. **(3)**

(v) Explain why the occupants of a house fitted with smoke detectors containing americium–241 are not at risk from alpha radiation emitted by these devices. **(3)**

(vi) Householders are advised to replace the batteries in smoke detectors regularly. Explain whether or not the americium–241 needs to be replaced regularly also. **(3)**

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

A



Diamond and graphite are macromolecular crystalline forms of carbon.
Explain in terms of bonding

(i) the hardness of diamond,

(ii) why graphite is soft and can be used as a lubricant,

(iii) the electrical conductivity of graphite. **(18)**

(iv) Buckminsterfullerene is another crystalline form of carbon that consists of football shaped clusters of 60 carbon atoms as shown. What type of bond joins the carbon atoms in these 'bucky balls'? **(3)**

(v) The spatial arrangement of carbon atoms in each of these three structures was established by analysing the scattering of X-rays by the crystals. What was the surname of the father and son who pioneered this technique? **(4)**

or

B

Oxygen is produced on an industrial scale by the liquefaction and fractional distillation of air.

(i) What substances are removed in the purification of the air feedstock before it is liquefied? **(4)**

(ii) Describe with the aid of a labelled diagram how the fractional distillation of the pure liquid air is carried out. **(9)**

(iii) Explain whether the fractional distillation of air is a continuous or a batch process. **(6)**

(iv) Name and give one industrial use of a co-product of the fractional distillation of air. **(6)**

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SOLUTION

11. (a) (i) Platinum. **(4)**

(ii) Through the movement of ions. **(3)**

(iii) (1) B **(3)**

(2) $H_2O \rightarrow 2H^+ + \frac{1}{2}O_2 + 2e^-$

TIP: Formulas **(3)**, Balancing **(3)**.

(iv) 17 **(3)**

(v) (1) A **(3)**

(2) Because OH^- are generated. **(3)**

(b) (i) Spontaneous random decay of a nucleus. **(3)**
To release α, β or γ radiation. **(2)**

(ii) Time taken for half of the radioactive isotopes **(3)**
in a sample to decay. **(2)**

(iii) A = 237 **(3)**
Z = 93 **(3)**

(iv) Causes ionisation. **(3)**

(v) Radiation is not very penetrating. **(3)**

(vi) Half-life is over 400 years. **(3)**

(c) **A:** (i) Tetrahedral. **(3)**
Covalently bonded carbon atoms forming strong crystals. **(3)**

(ii) Consists of layers of hexagonally bonded carbon atoms **(3)**
that can slide over each other. **(3)**

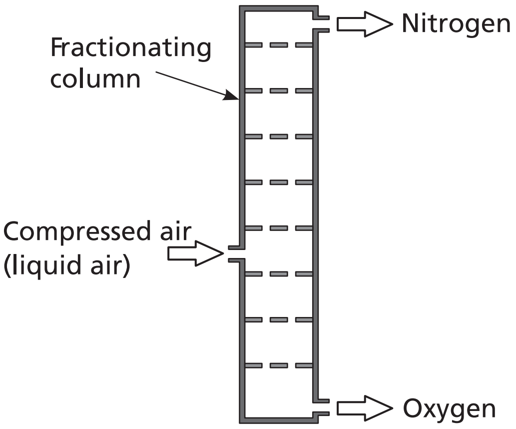
(iii) Delocalised. **(3)**
Electrons free to move along the layers. **(3)**

(iv) Covalent bonds. **(3)**

(v) Bragg. **(4)**

B: (i) Dust or moisture or carbon dioxide.

(ii) Relevant diagram with one correct label. **(Any 1 × 4)**
Compressed (liquid) air warms up in column.
Liquid oxygen comes off
at base of column.
Nitrogen comes off
at top of column. **(Any 3 × 3)**



(iii) Continuous.
The air is cooled and fractionated continuously. **(2 × 3)**

(iv) Co-product: Liquid nitrogen. **(3)**
Nitrogen: Fast freezing of fruit. **(3)**

SECTION A

Answer at least two questions from this section.

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

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

(a) Why are iron tablets sometimes medically prescribed? **(5)**

(b) (i) Why must potassium manganate(VII) solutions be standardised?

TIP: Ensure each of the three parts are addressed.

(ii) Why was it necessary to standardise the potassium manganate(VII) solution *immediately* before use in the titration?

(iii) What reagent is used for this purpose? **(9)**

(c) (i) Describe how exactly $250cm^3$ of Fe^{2+} solution was prepared from five iron tablets, each of mass 0.325g.

(ii) 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, $18.75cm^3$ of 0.01M potassium manganate(VII) was required to react with $25.0cm^3$ 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 $250cm^3$ of solution,

(iii) the percentage by mass of iron in the tablets. **(18)**

SOLUTION

1. **(a)** To prevent anaemia. **(5)**

(b) (i) As $KMnO_4$ is not a primary standard. **(3)**

(ii) It is unstable and decomposes in sunlight. **(3)**

(iii) Ammonium iron(II) sulfate. **(3)**

(c) (i) The tablets were crushed using a pestle and mortar, transferred to a beaker containing dilute sulfuric acid and dissolved. **(3)**

The solution was then transferred to a $250cm^3$ volumetric flask using a funnel and together with the rinsings from the beaker. **(3)**

- Make up to just below the graduation mark with deionised water.
- Remove funnel and make up to the graduation mark with deionised water using a plastic dropper.
- Ensure that the bottom of the meniscus is on the graduation mark.
- Stopper and invert 15–20 times. **(Any 1 × 3)**

(ii) Prevents oxidation of Fe^{2+} to Fe^{3+} by the oxygen in the air or the dissolved oxygen in the water. **(3)**

(d) To ensure complete reduction of Mn^{+7} to Mn^{+2}. **(3)**
To prevent formation of Mn^{+4}. **(3)**

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(e) $KMnO_4$ Fe^{2+}

$V_{ox} = 18.75$ $V_{red} = 25$

$M_{ox} = 0.01$ $M_{red} = ?$

$n_{ox} = 1$ $n_{red} = 5$

(i) $$\frac{V_{ox} \times M_{ox}}{n_{ox}} = \frac{V_{red} \times M_{red}}{n_{red}}$$

$$\frac{18.75 \times 0.01}{1} = \frac{25 \times M_{red}}{5}$$ **(3)**

$M_{red} = 0.0375$ moles/L **(3)**

(ii) 0.0375×56

$= 2.1$g/L **(3)**

$\div 4 = 0.525$g/250cm^3 **(3)**

(iii) Mass of iron in 1 tablet $= \frac{0.525}{5} = 0.105$g

$$\frac{0.105 \times 100}{0.325}$$ **(3)**

$= 32.3\%$ **(3)**

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) (i) Give the name or chemical formula of the solid **X** used in the preparation of ethene.

(ii) What is the colour of this solid? **(5)**

(b) (i) Write a balanced equation for the reaction involved in the preparation of ethene.

(ii) 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) (i) Give the name or formula of the solid **Y** used in the preparation of ethyne in the school laboratory.

(ii) Describe the appearance of this solid. **(6)**

(e) Both ethene and ethyne are described as *unsaturated*.

(i) What does this mean?

(ii) Describe a test you could carry out on a sample of either gas to show that it is unsaturated.

(iii) What would you observe during the test? **(9)**

(f) Both ethene and ethyne can be burned in air.

(i) What is the most noticeable difference seen when these combustions are carried out in a school laboratory?

(ii) Write a balanced equation for the complete combustion of either gas. **(9)**

(g) Give

(i) a major use of ethene,

(ii) a major use of ethyne. **(6)**

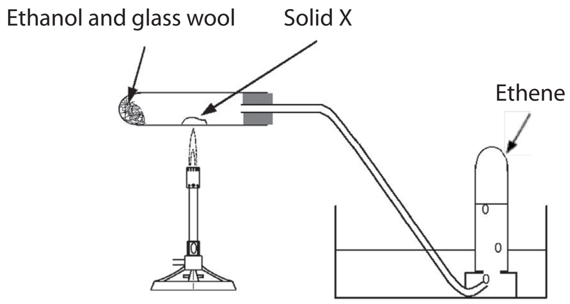


Diagram 1

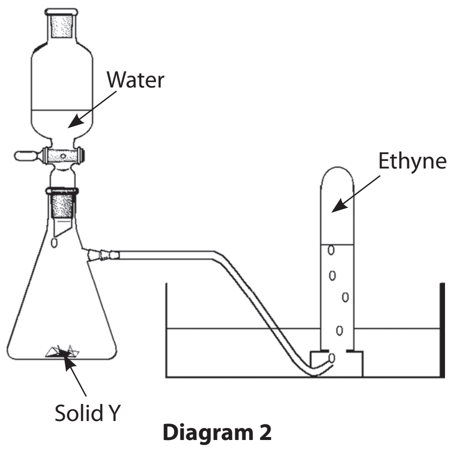


Diagram 2

SOLUTION

2. (a) (i) Aluminium oxide. **(3)**
(ii) White solid. **(2)**

(b) (i) $C_2H_5OH \rightarrow C_2H_4 + H_2O$ **(3)**
(ii) Elimination. **(3)**

(c) Keep gas away from flame.
Wear safety glasses.
Remove tube from water before removing the heat to prevent suck-back.
Avoid inhaling the glass wool. **(Any 3 × 3)**

(d) (i) Calcium carbide CaC_2. **(3)**
(ii) Grey black solid. **(3)**

(e) (i) Double bond present. **(3)**
(ii) Add bromine water or acidified potassium permanganate to gas. **(3)**
(iii) Solution goes colourless. **(3)**

(f) (i) Ethyne is more smoky and sooty. **(3)**
(ii) Ethene: $C_2H_4 + 3O_2 \rightarrow 2CO_2 + 2H_2O$

or

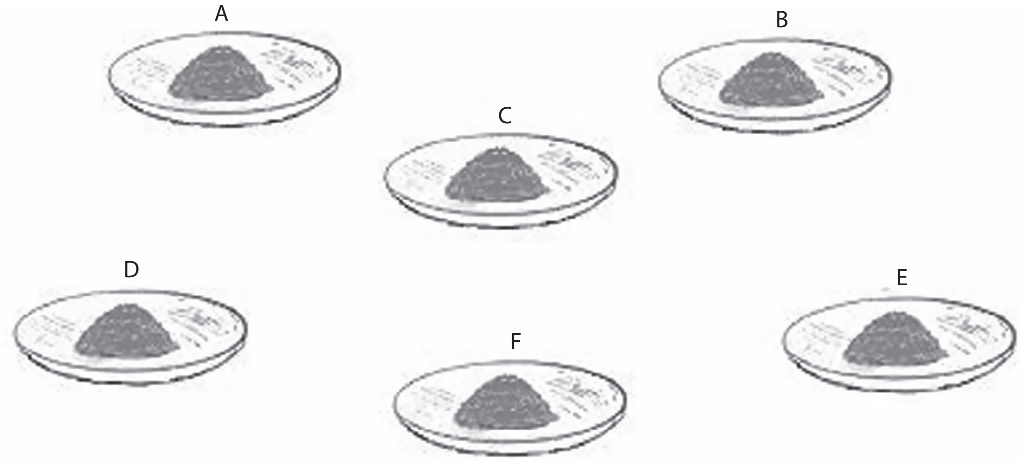
Ethyne: $C_2H_4 + 2\frac{1}{2}O_2 \rightarrow 2CO_2 + H_2O$

TIP: Formulas **(3)**, Balancing **(3)**.

(g) (i) Ethene: Polyethene, ripening fruit. **(Any 1 × 3)**
(ii) Ethyne: Cutting metals, welding metals. **(Any 1 × 3)**

QUESTION 3

The clock glasses shown in the diagram contained pure samples of the following salts: **KCl**, **KNO_3**, **$Na_2HPO_4 \cdot 12H_2O$**, **$Na_2SO_3 \cdot 7H_2O$**, **$NaHCO_3$** and **$Na_2SO_4 \cdot 10H_2O$**. 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)**

(b) (i) 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?
(ii) 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.
(i) What was the other reagent?
(ii) 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)**

TIP: Needs three relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

(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, $\mathbf{BaCl_2}$, was then added to solutions of each of the three remaining samples in turn. A white precipitate was produced in two cases.

(i) Write a balanced equation for either **one** of the two reactions that occurred.

The student then added dilute hydrochloric acid to the precipitates.

(ii) What would the student have observed and

(iii) 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)**

SOLUTION

3. **(a)** Introduce the salt into Bunsen flame. **(2)**
Using a platinum wire or a soaked splint. **(3)**
Sodium gives a yellow colour. **(3)**
Potassium gives a lilac colour. **(3)**

(b) (i) KCl **(3)**
(ii) A white precipitate forms. **(3)**

(c) (i) Iron(II) sulfate. **(3)**
(ii) KNO_3 **(3)**

(d)
- Add ammonium molybdate to the salt solution. **(3)**
- Add a few drops of concentrated nitric acid. **(3)**
- A yellow precipitate forms. **(3)**

(e) (i) $Ba^{2+} + SO_4^{2-} \rightarrow BaSO_4$

TIP: Formulas **(3)**, Balancing **(3)**.

OR

$Ba^{2+} + SO_3^{2-} \rightarrow BaSO_3$

(ii) If the precipitate dissolves confirms it is a sulfite salt. **(3)**
(iii) If the precipitate remains it is the sulfate salt. **(3)**

(f) Last salt is sodium hydrogencarbonate.
The addition of HCl **(3)**
results in carbon dioxide being given off. **(3)**

SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

(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.

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

(c) State the *Heisenberg uncertainty principle*.

(d) Define *bond energy*.

(e) Define a conjugate pair according to the Brønsted–Lowry theory.

TIP: Ensure you give the definition in terms of the Brønsted–Lowry theory and not Arrhenius.

(f) Calculate the pH of a 0.025M solution of nitric acid.

(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.

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

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

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

(i) 

(ii) 

(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.

SOLUTION

4. **(a)** Robert Millikan. **(3)**
Electron. **(3)**

(b) Number of neutrons decrease(s) by 1, number of protons increase(s) by 1. **(6)**

(c) Not possible to measure the exact position (location) and momentum (energy, velocity) of an electron. **(3)**
In atom simultaneously. **(3)**

(d) Average energy required to break a bond and **(3)**
to separate the atoms completely from each other. **(3)**

(e) An acid and base differing by proton. **(6)**

(f) $-\log_{10} 0.025 = 1.6$ **(3 + 3)**

(g) Calcium carbonate. **(6)**

(h) O-H **(3)**
COOH **(3)**

(i) $C_2H_6 + Cl_2 \longrightarrow C_2H_5Cl + HCl$ ← **TIP:** Formulas **(3)**, Balancing **(3)**.

(j) Oxidising agent. **(3)**
Toxic or poisonous. **(3)**

(k) **(A)** Polymerisation of alkenes. **(6)**
(B)

(i) $2NH_3 + CO_2 \longrightarrow (NH_2)_2CO + H_2O$

(ii) $4NH_3 + 5O_2 \longrightarrow 4NO + 6H_2O$

(iii) $Ca(OH)_2 + MgCl_2 \longrightarrow Mg(OH)_2 + CaCl_2$ ← **TIP:** Formulas **(3)**, Balancing **(3)**.

QUESTION 5

(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 ionisation energy versus atomic number for the elements with atomic numbers from 10 to 20 inclusive. **(12)**

(c) Account fully for ← **TIP:** You need to give any relevant exceptions for full explanation.

(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)**

(d) (i) Write the *s*, *p* electron configuration for the potassium atom.

Hence state how many (ii) energy sub-levels, (iii) individual orbitals, are occupied by electrons in a potassium atom.

(iv) Explain why there are electrons in the fourth main energy level of potassium although the third main energy level is incomplete. **(12)**

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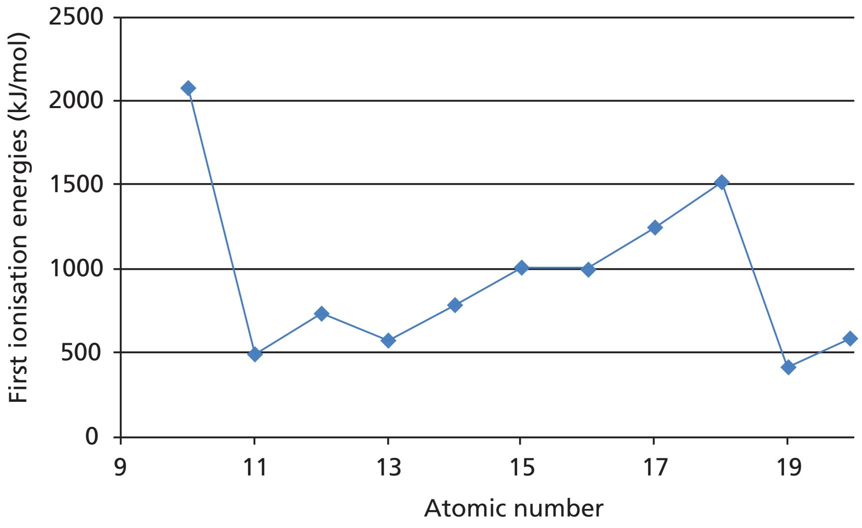
SOLUTION

5. **(a)** The minimum energy required to remove the most loosely bound electron from a neutral gaseous atom **(5)** in the ground state. **(3)**

(b)



MARKS:

Graph axes labelled correctly. **(3)**

Axes scaled correctly. **(3)**

Points plotted correctly. **(3)**

Graph drawn correctly. **(3)**

(c) (i) Ionisation energies increase across the periodic table due to:

Increased nuclear charge. **(3)**

Decrease in atomic radius. **(3)**

(ii) Element 12 has a full outer sublevel which gives increased stability. **(3)**

Element 15 has a half-filled sublevel which gives increased stability. **(3)**

(iii) Element 18 has a full outer sublevel. **(3)**

Element 19 has an electron in the fourth shell which is further from the nucleus. **(3)**

(d) (i) $1s^22s^22p^63s^23p^64s^1$ **(3)**

(ii) 6 sublevels. **(3)**

(iii) 10 orbitals. **(3)**

(iv) 4s sublevel is lower in energy then the 3d. **(3)**

QUESTION 6

(a) Define (i) hydrocarbons, (ii) structural isomers. **(8)**

(b) (i) Give a use for the kerosene fraction obtained when crude oil is fractionated.

(ii) Explain why some of the kerosene produced in oil refining is subjected to catalytic cracking. **(9)**

(c) Straight chain molecules of $C_{13}H_{28}$ occur in the kerosene fraction. Upon cracking a molecule of $C_{13}H_{28}$, a C_2H_4 molecule, a C_4H_8 molecule and an unbranched alkane molecule are obtained.

(i) Identify this unbranched alkane molecule and

(ii) State its octane number.

(iii) Draw structures for three of the isomers of 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 C_4H_8 isomers is described by the following balanced equation.

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

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

SOLUTION

6. **(a)** (i) Compounds containing hydrogen and carbon only. **(4)**

(ii) Compounds with the same molecular formula but different structural formula. **(4)**

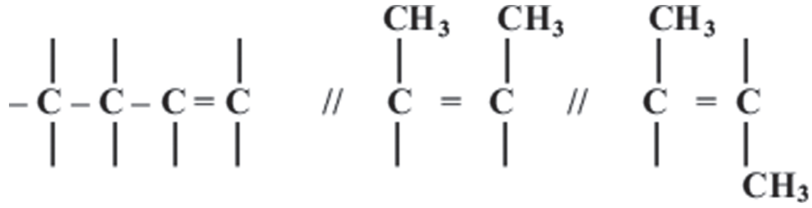
(b) (i) Used in aviation fuel.

(ii) Greater demand for shorter molecules. **(6 + 3)**

(c) (i) Heptane. **(3)**

(ii) Octane number = 0 **(3)**

(iii)



(3 × 3)

(d) Isomerisation. **(3)**

Reforming. **(3)**

(e) $4C + 4O_2 \longrightarrow 4CO_2$ $\Delta H = -1576$kJ/mol **(3)**

$4H_2 + 2O_2 \longrightarrow 4H_2O$ $\Delta H = -1144$kJ/mol **(3)**

$4CO_2 + 4H_2O \longrightarrow C_4H_8 + 6O_2$ $\Delta H = 2710$kJ/mol **(3)**

$4C + 4H_2 \longrightarrow C_4H_8$ $\Delta H = -10$kJ/mol **(3)**

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 micro-organism in concentration or numbers that constitute a potential danger to human health.*

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

TIP: Use bullet points and put in as many points as you can remember.

(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?

TIP: Only one problem was required for full marks.

(iv) EU standards specify that the concentration of lead (in the form of Pb^{2+}) in drinking water must be below 10µg/l (micrograms per litre). (1) Why must the Pb^{2+} concentration be kept so low? (2) 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) (1) What are the nutrients referred to above? (2) 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 $50cm^3$ to 5.0 litres with well-aerated pure water.

TIP: Note the dilution factor for calculation.

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 9.8ppm and 4.7ppm, respectively, were recorded.

(1) What are the suitable conditions for, and the duration of, storage of the second sample?

TIP: Use bullet points and put in as many points as you can remember.

(2) Calculate the BOD of the brewery effluent. **(18)**

SOLUTION

7. **(a)** (i)
- Settlement. **(5)**
- Flocculation/clumping together of smaller particles into larger particles.

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- Decant the clear water.
- Filtration through sand and gravel beds. **(2 × 3)**

(ii) Chlorination. **(3)**

(iii) Corrosion of pipes. **(3)**

(iv) (1) Lead is poisonous. **(3)**

(2) Precipitation. **(3)**

(b) (i) (1) Nitrates and phosphates. **(6)**

(2) Tertiary treatment. **(3)**

(ii) (1)
- In the dark. **(3)**
- 20°C **(3)**
- 5 days **(3)**

(2) $9.8 - 4.7 = 5.1$ **(3)**
5.1×100 **(3)**
$= 510$ppm **(3)**

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) (i) Name the family (homologous series) of organic compounds to which compound **B** belongs.

(ii) Name the aromatic compound, found in almond kernels, that has the same functional group as compound **B**. **(9)**

(c) (i) Which of the compounds **A**–**D** is present in concentrations of about 40% (v/v) in whiskey?

(ii) Which of the other compounds is formed as the primary metabolite of this compound in the human body? **(6)**

(d) (i) Describe what is observed when a small amount of sodium carbonate is added to a test tube containing an aqueous solution of compound **C**.

(ii) Write a balanced equation for the reaction.

(iii) Name the flavouring agent that consists of an approximately one molar solution of compound **C**.

(iv) 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)**

SOLUTION

8. (a) A= Ethanol. **(3)**
B = Ethanal. **(3)**
C = Ethanoic acid. **(3)**
D = Ethyl ethanoate. **(3)**

(b) (i) Aliphatic aldehydes.
(ii) Benzaldehyde. **(6+3)**

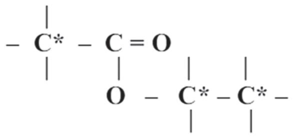
(c) (i) A – Ethanol **(3)**
(ii) B – Ethanal **(3)**

(d) (i) Gas (CO_2) produced. **(3)**
(ii) $2CH_3COOH + Na_2CO_3 \rightarrow 2CH_3COONa + H_2O + CO_2$

TIP: Formulas **(3)**, Balancing **(3)**.

(iii) Vinegar. **(3)**
(iv) $\frac{60}{10} = 6\%$ (w/v) **(3)**

(e)



MARKS:
Drawing the formula. **(5)**
Carbons labelled correctly. **(3)**

QUESTION 9

(a) (1) 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.

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

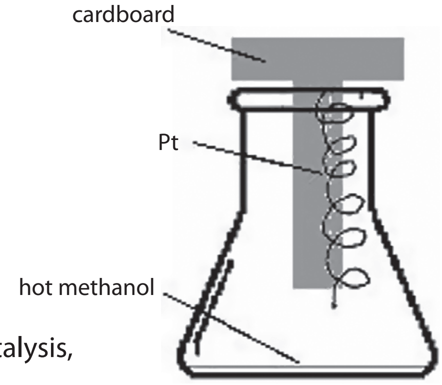
(2) Describe how the time for the reaction between the solutions of hydrochloric acid and sodium thiosulfate was obtained at room temperature. **(6)**

> **TIP:** Use bullet points and put in as many points as you can remember. Only refer to the procedure involving the experiment being done at room temperature.

(3) In a reaction mixture what effect, if any, does an increase in temperature of 10K 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.



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

SOLUTION

9. (a) (1) (i) Minimum energy required for colliding particles to react. **(5)**

(ii) An effective collision is where reactants reach activation energy. **(3)**

(2)
- Add the hydrochloric acid to the sodium thiosulfate and start clock. **(3)**
- Stop clock and note time when cross underneath the flask becomes invisible when viewed through the solution. **(3)**

(3) (i) Small increase. **(3)**

(ii) Large increase. **(3)**

(iii) No effect. **(3)**

(b) (i) Wire (Pt) glows. **(3)**

(ii) Methanal, hydrogen, water. **(Any 2 × 3)**

(iii) Heterogeneous catalysis. **(3)**

(iv) The platinum lowers activation energy. **(6)**

(v) A catalytic poison is preferentially adsorbed preventing other reaction(s). **(3)**

(vi) Reactant: Hydrogen peroxide (H_2O_2). **(3)**

Catalyst: Manganese(IV) oxide (manganese dioxide). **(3)**

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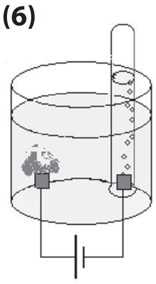
QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(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)**

(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)**

(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)**

SOLUTION

10. (a) Equal volumes of gases contain equal numbers of molecules. **(4)**
Under the same conditions of temperature and pressure. **(3)**
Gases made up of particles in rapid, random, straight-line motion.
Volume of particles are negligible.
No forces of attraction between molecules.
Average kinetic energy of molecules proportional to Kelvin temperature. **(Any 2 × 3)**
Real gases differ from ideal gases:
Forces of attraction between the molecules. **(3)**
Volume is not negligible. **(3)**

$\frac{1.8 \times 10^{24}}{2} = 9 \times 10^{23}$ molecules **(3)**

$\frac{9 \times 10^{23}}{6 \times 10^{23}} = 1.5$ moles **(3)**

(b) Loss of electrons. **(4)**
(i) Platinum. **(3)**
(ii) Anode: $I^- \rightarrow ½I_2 + e^-$

TIP: Formulas **(3)**, Balancing **(3)**.

Cathode: $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

TIP: Formulas **(3)**, Balancing **(3)**.

(iii) A brown colour is produced due the formation of iodine. **(6)**

(c) (i) Atoms of same element (same atomic number) having different mass numbers **(4)** due to different number of neutrons in the nucleus. **(3)**
(ii) Positive ions separated **(3)**
based on relative mass(es) **(3)**
when moving in a magnetic field. **(3)**
(iii) $90.5 \times 20 = 1810$ **(3)**
$9.5 \times 22 = 209$ **(3)**
$100 = 2019$
$A_r = 20.19$ **(3)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

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

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

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

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.

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

(ii) (1) Deduce from the data whether this reaction is exothermic or endothermic.
(2) 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)**

(b) (i) Use a dot and cross diagram to show the bonding in an ammonia, NH_3, molecule. **(7)**

(ii) (1) Use electron pair repulsion theory to determine the shape of the ammonia molecule.
(2) Explain clearly why the bond angle in ammonia is only 107°. **(9)**

(iii) Hydrogen bonding occurs between ammonia molecules.
(1) What are *hydrogen bonds*?
(2) Draw a diagram illustrating hydrogen bonding in ammonia. **(9)**

(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)**

SOLUTION

11. (a) (i) $T = 573$K $P = 1000$atm **(4)**

(ii) (1) The forward reaction is exothermic. **(3)**
(2) More NH_3 (product) at lower temperatures. **(3)**

(iii) High costs or danger of explosions. **(3)**

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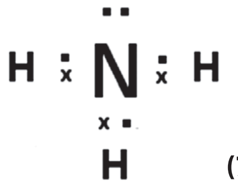
(iv) $K_c = \dfrac{[NH_3]^2}{[N_2][H_2]^3}$ **(6)**

(v) (1) No effect on the position of equilibrium. **(3)**

(2) The system reaches equilibrium faster but yield unchanged. **(3)**

(b) (i)



(7)

(ii) (1) Three bonding and one lone pair. **(3)**

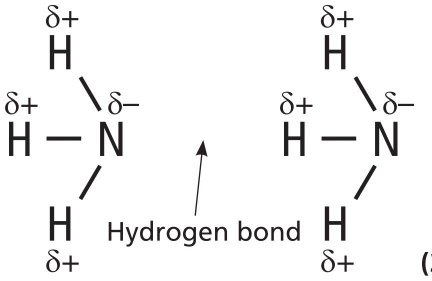
Pyramid. **(3)**

(2) Greater repulsion of lone pair pushes bonds closer together. **(3)**

(iii) (1) Intermolecular interaction **(3)**

Involving the slightly δ+ hydrogen (H) atom and slightly δ- nitrogen atom **(3)**

(2)



(3)

(c) **A**

(i) Ores are very stable. **(4)**

(ii) To allow movement of ions. **(3)**

To lower the melting point of the electrolyte. **(3)**

(iii) $NaCl \longrightarrow Na + 1/2\ Cl_2$

TIP: Formulas **(3)**, Balancing **(3)**.

Separated by steel mesh. **(3)**

Sodium used in street lighting. **(3)**

Chlorine used in swimming pools. **(3)**

B

(i) $O_3 \longrightarrow O_2 + O^{\cdot}$

$O_2 + O^{\cdot} \longrightarrow O_3$ **(4 + 3)**

(ii) $O_3 \longrightarrow O_2 + O^{\cdot}$ **(3)**

(iii) Sunburn.

Skin cancer.

Eye damage. **(Any 2 × 3)**

(iv) Refrigerant.

Air-conditioning.

Fire extinguishers. **(Any 1 × 3)**

(v) Dichlorodifluoromethane. **(3)**

(vi) Hydrochlorofluorocarbons. **(3)**

SECTION A

Answer at least two questions from this section.

QUESTION 1

To determine the concentration of ethanoic acid, $\mathbf{CH_3COOH}$, in a sample of vinegar, the vinegar was first diluted and then titrated against 25.0cm^3 portions of a previously standardised 0.10M 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 22.7cm^3, respectively.

TIP: You need to get the average of these two figures to use as titre figure for calculations.

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

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

TIP: You need to give the procedure for measuring and diluting. Use bullet points and give as many points as you can.

(c) The equation for the titration reaction is:

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

(i) Name an indicator suitable for this titration.

(ii) Justify your choice of indicator.

TIP: You need to state the type of acid–base titration in this experiment.

(iii) State the colour change. **(12)**

TIP: You need to give both colours.

(d) Calculate the concentration of the diluted solution of ethanoic acid in

TIP: No dilution factor is needed for this part of the calculations.

(i) moles per litre,

(ii) grams per litre.

State the concentration of ethanoic acid in the original vinegar sample in grams per litre.

TIP: Now multiply up by the dilution factor.

Express this concentration in terms of % (w/v). **(15)**

TIP: g/100cm^3

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

SOLUTION

1. (a) If the vinegar was not diluted, a large volume of NaOH would be needed to get a reasonable titration figure. **(5)**

(b)
- Rinse the pipette with deionised water.
- Then rinse the pipette with the vinegar solution.
- Fill using a pipette filler ensuring the bottom of the meniscus is on the graduation mark, reading it at eye level.
- Allow the vinegar to flow into a 250cm^3 volumetric flask.
- Add deionised water to just below the graduation mark.
- Using a dropper add deionised water until the bottom of the meniscus is on the graduation mark, reading at eye level.
- Stopper the flask and invert several times to ensure complete mixing. **(Any 5 × 3)**

(c) (i) Phenolphthalein. **(3)**

(ii) As this is a weak acid-strong base titration with an end point, the pH jumps from 6 to 11 approx. **(3)**

(iii) Pink **(3)**
to colourless. **(3)**

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(d) CH_3COOH NaOH

$V_a = 22.65$ (mean titre) $V_b = 25$

$M_a = ?$ $M_b = 0.01$

$n_a = 1$ $n_b = 1$

$$\frac{V_a \times M_a}{n_a} = \frac{V_b \times M_b}{n_b}$$ **(3)**

$$\frac{22.65 \times M_a}{1} = \frac{25 \times 0.01}{1}$$

$M_a = 0.11$moles/L (dilute solution) **(3)**

$0.11 \times 60 = 6.6$g/L **(3)**

$0.11 \times 10 = 1.1$moles/L

$1.1 \times 60 = 66$g/L **(3)**

6.6% w/v **(3)**

(e) Methanoic acid (HCOOH). **(3)**

QUESTION 2

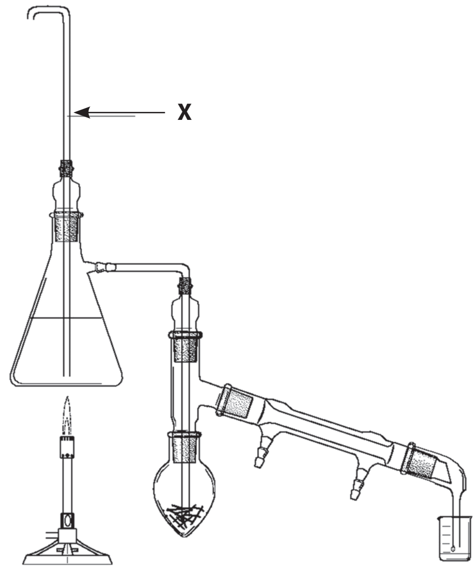
Chromatography is widely used in chemistry as a separation technique.

(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)**

TIP: You only need to do one of the three.

(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°C and avoids the delicate organic molecules being damaged at high temperatures.



(c) What is meant by the term *immiscible liquids*? **(3)**

(d) (i) Name a substance you isolated by steam distillation in the school laboratory (ii) and the plant material from which it was extracted. **(6)**

(e) Explain the function of the tube labelled **X**. **(6)**

(f) (i) Describe the appearance of the distillate collected.

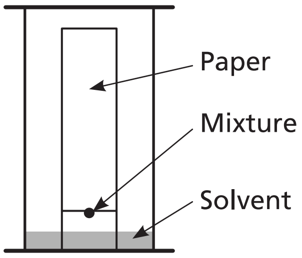
(ii) Name or describe briefly a technique that could be used to separate the organic substance from the water. **(9)**

(g) In a steam distillation experiment 20.0g of plant material were heated in the presence of steam.

Only 0.250g of pure organic liquid was obtained. Calculate the percentage yield. **(5)**

SOLUTION

2. **(a)** Paper chromatography.



Apply mixture to be separated on the paper using a dropper. **(3)**
Place just above the solvent (eluent). **(3)**
Place the paper in a beaker containing the solvent. **(3)**
The solvent moves up the paper. **(3)**
State or show separation of components of the mixture. **(3)**

(b) The components in the mixture have different interaction with the stationary and mobile phases. **(6)**

(c) Liquids that do not mix. **(3)**

(d) (i) Substance: Clove oil. **(3)**

(ii) Plant material: Cloves. **(3)**

(e) X is a safety tube that releases pressure. **(6)**

(f) (i) Cloudy milky liquid. **(6)**

(ii) Separated using solvent extraction. **(3)**

(g) % Yield: $\frac{0.25}{20} \times 100 = 1.25\%$ **(5)**

QUESTION 3

(a) Hydrogen peroxide solution is an oxidising reagent. Draw *or* describe the warning symbol put on 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

(i) Plot a graph of the volume of gas produced *versus* time.

TIP: Use graph paper with axes labelled and points plotted as accurately as possible with time on *x* and volume on *y*.

(ii) 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,

TIP: Draw tangent to curve at 5 mins, and calculate the slope of tangent to curve at 5 mins.

(ii) calculate the total mass of gas produced in this experiment. **(12)**

TIP: Calculations done at room temperature and pressure. Use 24L to convert to moles.

SOLUTION

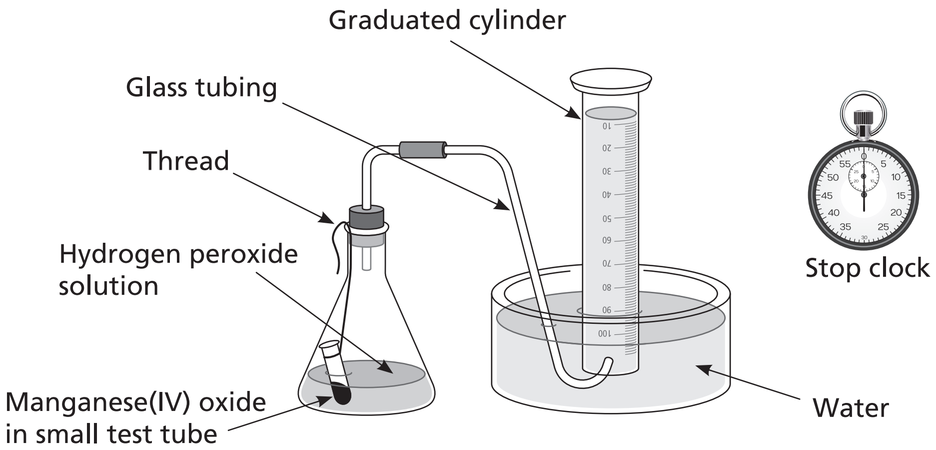
3. (a)

(5)

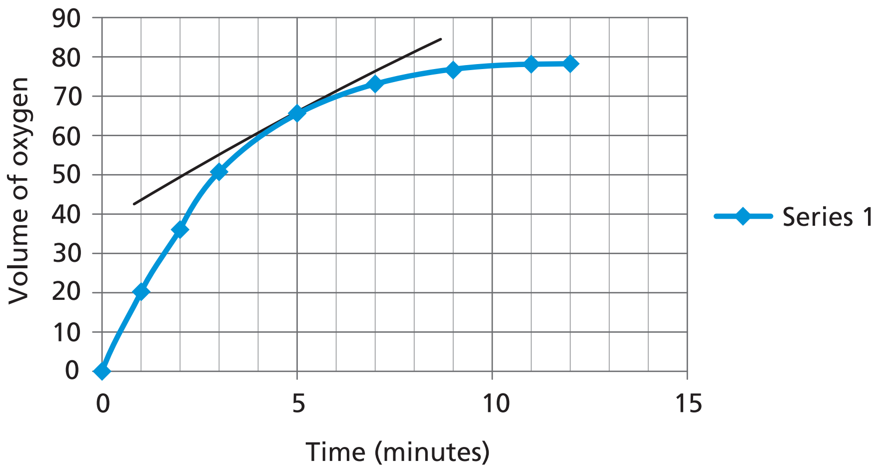
(b) $H_2O_2 \rightarrow H_2O + \frac{1}{2}O_2$ **(3 + 3)**

TIP: Formulas **(3)**, Balancing **(3)**.

(c) Apparatus with H_2O_2. **(3)**
Arrangement for mixing at precise time. **(6)**
Suitable method of monitoring. **(3)**



(d) (i) Axes correctly labelled with numbers. **(3)**
Axes with correctly labelled units. **(3)**
Eight points accurately plotted. **(3)**
Curve drawn firm (0, 0). **(3)**



(ii) The start of the reaction has the fastest rate of reaction. **(3)**

(e) (i) Instantaneous rate at 5 mins = slope of tangent to curve 4.0–6.0 cm^3/min. **(6)**

(ii) Total volume = $78cm^3$

No. of moles $= \frac{78}{24000} = 0.00325$ moles **(3)**

$0.00325 \times 32 = 0.104g$ **(3)**

SECTION B

QUESTION 4

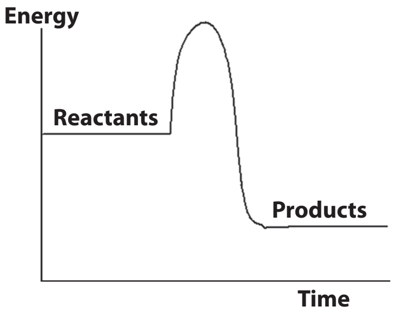
Answer **eight** of the following items (a), (b), (c), etc. **(50)**

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

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

(c) Give **two** properties of alpha particles.

(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.



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

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

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

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

(i) What is the purpose of tertiary treatment of sewage?

(j) Complete and balance the equation:

TIP: Formulas **(3)**, Balancing **(3)**.

$$C_2H_5OH + Na \longrightarrow$$

(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.

SOLUTION

4. (a) $[1s^2 2s^2 2p^6]^{3+}$ **(6)**

(b) Number of protons in nucleus. **(6)**

(c) Positive (+) charge (attracted to negative). Low velocity. Poor penetration. **(Any 2 × 3)**

(d) Infra-red **(6)**

(e) (i) $Ca(HCO_3)_2$ **(3)**

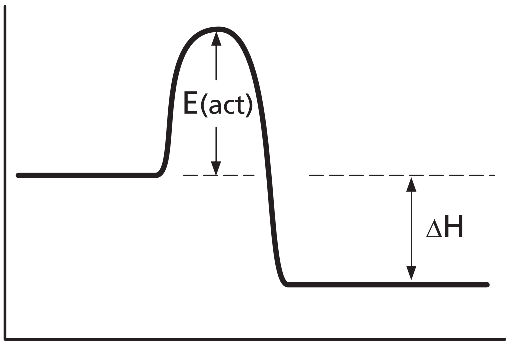
(ii) $CaSO_4$ **(3)**

(f) Platinum, palladium, rhodium. **(Any 2 × 3)**

(g) Lone pair(s) of electrons in water. **(3)**
Have greater repelling power (repulsion). **(3)**

(h) (i) Activation energy correctly shown. **(3)**

(ii) ΔH correctly shown. **(3)**



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(i) Remove nitrogen compounds (nitrates) and phosphorus compounds (phosphates). **(6)**

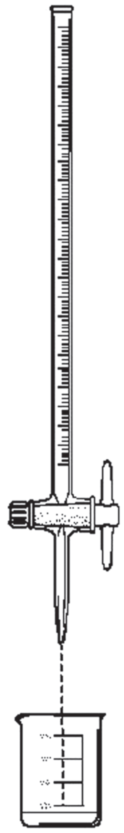
(j) $C_2H_5OH + Na \rightarrow C_2H_5ONa + ½H_2$ (Formulas **(3),** Balancing **(3)**.)

(k) **(A)** Lightning. **(3)**
Bacteria. **(3)**

OR

(B) Steel less brittle. **(3)**
More useful. **(3)**

QUESTION 5



(a) Define *electronegativity*. **(5)**

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

(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) (i) Use your knowledge of intermolecular forces to explain why methane has a very low boiling point (b.p. = –164°C).

(ii) 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°C). 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.

(i) Account for these observations.

(ii) 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)**

SOLUTION

5. **(a)** Relative attraction **(3)**
that an atom in a molecule has for a shared pair of electrons in a covalent bond. **(2)**

(b) (i) Decrease. **(3)**

(ii) Increasing atomic radius. **(3)**
Increased shielding (screening). **(3)**

(c) (i) Water: Polar covalent. **(3)**

(ii) Methane: Covalent. **(3)**

(iii) Magnesium chloride: Ionic. **(3)**

(d)

(3 + 3)

(e) Attractive forces between molecules. **(6)**

(f) (i) Very weak intermolecular forces. **(3)**

(ii) Much stronger hydrogen bonds. **(3)**

(g) (i) Polarity of water causes attraction to charged rod. **(3)**
Non-polarity of cyclohexane means it is not affected by charged rod. **(3)**

(ii) Stream of water still attracted to rod as molecules (dipoles) arrange themselves with positive pole towards rod. **(3)**

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)**

TIP: Definition.

(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.

(1) Give another example of an oxygenate.

(2) Give two reasons why oxygenates are added to petrol. **(9)**

(b) (i) Write a balanced chemical equation for the combustion of ethanol, C_2H_5OH.

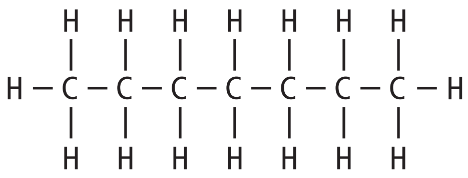
TIP: Formulas **(3)**, Balancing **(3)**.

(ii) 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)**

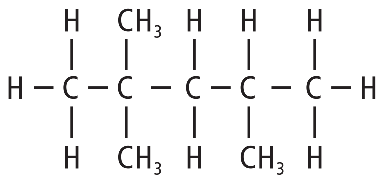
SOLUTION

6. **(a)** (i) A measure of the tendency of a fuel to resist knocking. **(5)**

(ii)



Heptane **(3)**



2,2,4-trimethylpentane. **(3)**

(iii) Light gasoline. **(3)**
Naphta. **(3)**

(iv) Removal of hydrogen. **(3)**
Ring formation. **(3)**

(v) (1) Methanol. **(3)**
(2) Raise the octane number. **(3)**
Less pollution. **(3)**

(b) (i) $C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ (Formulas **(3)**, Balancing **(3)**.)

(ii) $2C + 2O_2 \rightarrow 3CO_2$ –788kJ **(3)**

$3H_2 + \frac{3}{2}O_2 \rightarrow 3H_2O$ –858kJ **(3)**

$C_2H_5OH \rightarrow 2C + 3H_2 + \frac{1}{2}O_2$ +278kJ **(3)**

$C_2H_5OH + 3O_2 \rightarrow 2CO_2 + 3H_2O$ –1368kJ **(3)**

QUESTION 7

A chemical equilibrium is established when eleven moles of hydrogen and eleven moles of iodine are mixed at a temperature of 764K. 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 of the mixture is pale pink and there are seventeen moles of hydrogen iodide present.

The equilibrium is represented by the equation

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

colourless **purple** **colourless**

TIP: Definition.

(a) (i) What is meant by *chemical equilibrium*?

(ii) When the colour of the mixture has become pale pink, has reaction ceased? (iii) 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 764K. **(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)**

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

SOLUTION

7. (a) (i) A state where the rate of the forward reaction equals the rate of the reverse reaction. **(5)**

(ii) No. **(3)**

(iii) Both forward and reverse reactions still occur. **(3)**

(b) (i) $K_c = \dfrac{[HI]^2}{[H_2][I_2]}$ **(6)**

(ii)

	H_2	I_2	2HI
Initial	11	11	0
Change	$-1x$	$-1x$	$+2x$
At equilibrium	2.5 **(3)**	2.5 **(3)**	17

$0 + 2x = 17$

$x = 8.5$

$K_c = \dfrac{[17]^2}{[2.5][2.5]}$ **(3)**

$= 46.24$ **(3)**

(c) If a stress is applied to a system at equilibrium, **(3)**

The system readjusts to relieve the applied stress. **(3)**

(i) Lower yield of hydrogen iodide. **(3)**

The reaction goes in an exothermic direction which is the backwards reaction. **(3)**

(ii) More purple. **(3)**

(i) No change. The reaction goes in an exothermic direction which is the backwards reaction. **(3)**

(ii) Equal numbers of molecules on both sides of equation. **(3)**

QUESTION 8

(a) (i) Write an expression for the self-ionisation of water. **(5)**

TIP: Formulas **(3)**, Balancing **(2)**.

(ii) Define K_w, the ionic product of water.

The value of K_w at 25°C is 1.0×10^{-14}. Show that the pH of pure water is 7.0 at 25°C. **(12)**

(iii) Calculate the pH of a 0.5M solution of a strong monobasic (monoprotic) acid.

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

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

TIP: Use bullet points and give as many points as you can.

(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)**

TIP: You need to give the purpose for **each** chemical.

SOLUTION

8. (a) (i) $H_2O \rightleftharpoons H^+ + OH^-$ **(5)**

(ii) $K_w = [H^+][OH^-]$ **(3)**

$[H^+][OH^-] = 1 \times 10^{-14}$ **(3)**

But given $[H^+] = [OH^-]$

$[H^+] = 1 \times 10^{-7}$ **(3)**

$pH = -\log_{10}(1 \times 10^{-7})$

$= 7$ **(3)**

(iii) $pH = -\log_{10}([H^+])$

$pH = -\log_{10}(0.5)$

$= 0.3$ **(3)**

$H^+ = \sqrt{K_a \times M_a}$ **(3)**

$\sqrt{1.8 \times 10^{-5} \times 0.5}$ **(3)**

$= 0.003$

$pH = -\log_{10}[H^+]$

$= -\log_{10}(0.003)$

$= 2.52$ **(3)**

(b) (i)
- Settlement.
- Flocculation.
- Decanting.
- Filtration. **(Any 3 × 3)**

(ii) Chlorine. **(3)**
To sterilise the water. **(3)**
Sodium fluoride. **(3)**
Prevents tooth decay. **(3)**

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QUESTION 9

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) (i) Draw the structure of any one of the isomers of the third member of the alkene series. (ii) Indicate clearly which carbon atoms have planar bonding and which are bonded tetrahedrally. **(12)**

> **TIP:** The third member of the alkenes has four carbons as the first member has two carbons.

(c) Explain the term *unsaturated*. **(6)**

(d) The ionic addition mechanism for the reaction of ethene with bromine water involves the formation of an intermediate ionic species.

(i) Draw the structure of this species.

(ii) 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.

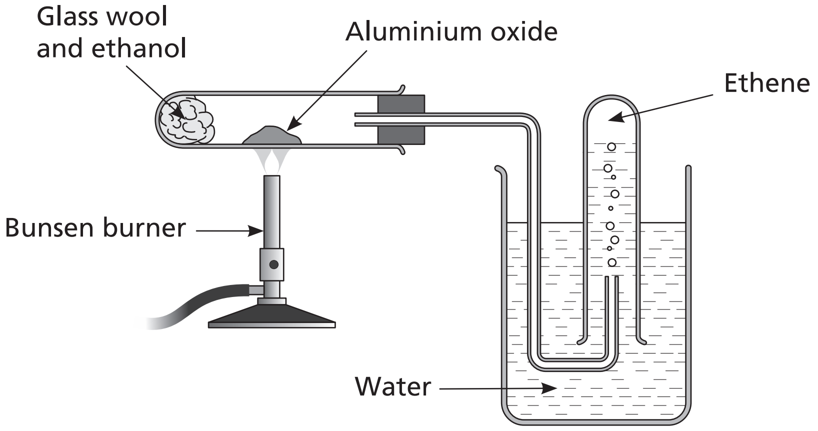
(iii) How does the formation of these three products support the mechanism of ionic addition? **(18)**

(e) (i) Name the polymer formed when ethene undergoes addition polymerisation.

(ii) Draw **two** repeating units of this polymer. **(6)**

SOLUTION

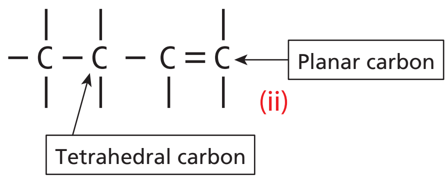
9. (a)



Ethanol and glass wool. **(4)**

Aluminium oxide and heat in correct position. **(4)**

(b) (i)

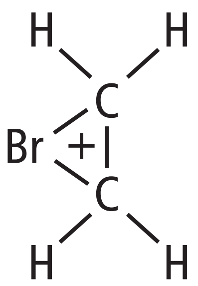


Correct structure. **(6)**

Correct labelling. **(6)**

(c) A molecule having a double or triple carbon–carbon bond. **(6)**

(d) (i)



(6)

(ii) 1,2-dibromoethane.

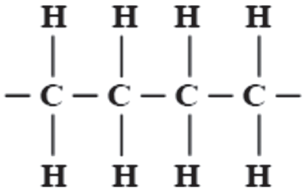
2-bromoethanol.

1-bromo-2-chloroethane. **(3 × 3)**

(iii) The addition of other anions giving different products proves the existence of a positive intermediate. **(3)**

(e) (i) Polyethene. **(3)**

(ii)



(3)

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(a) 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)**

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

(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)**

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

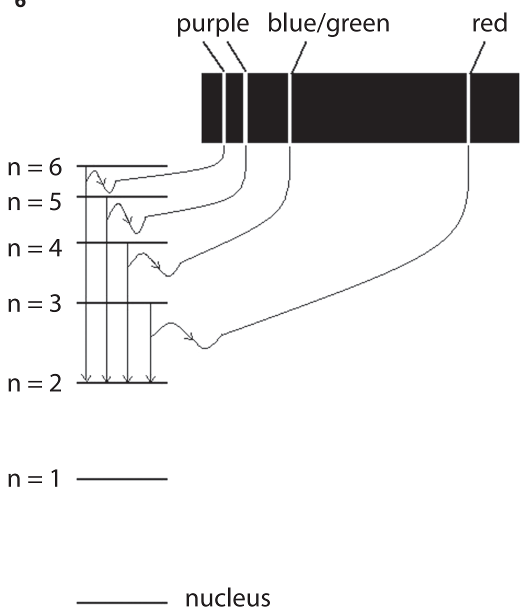
$$I_2 + S_2O_3^{2-} \rightarrow I^- + S_4O_6^{2-}$$

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

(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)**

SOLUTION

10. (a) (i) Suspended solids.

Filter a known volume of water through a weighed filter paper.

Dry the filter paper.

Reweigh the filter paper and find the mass of the suspended solids.

Express answer in mg/L. **(Any 3 × 3)**

(ii) Dissolved solids.
Evaporate a known volume of water to dryness.
In a container previously weighed.
Cool, reweigh and find the mass of the dissolved solids.
Express answer in mg/L. **(Any 3 × 3)**

(iii) Add silver nitrate and nitric acid.
To give white precipitate which is soluble in ammonia. **(4 + 3)**

(b) (i) Oxidation is the loss of electrons. **(4)**

(ii) Oxidation is an increase in oxidation number. **(3)**

(iii) $ClO^- + I^- + H^+ \rightarrow Cl^- + I_2 + H_2O$
−1 0
I^- goes from −1 to 0 and so is oxidised. **(3)**
$I_2 + S_2O_3 \rightarrow I^- + S_4O_6^{2-}$
0 −1
I_2 reduced, therefore it is the oxidising agent. **(3)**

(iv) $ClO^- + 2I^- + 2H^+ \rightarrow Cl^- + I_2 + H_2O$ **(2 × 3)**
$I_2 + 2S_2O_3 \rightarrow 2I^- + S_4O_6^{2-}$ **(2 × 3)**

(c) (i) An energy level is the fixed energy value of an electron in the atom may have. **(4)**

(ii) Ground state: Lowest energy state n = 1. **(3)**
Excited state: Higher energy state n > 1. **(3)**

(iii) Balmer series. **(3)**

(iv) $E_2 - E_1$: Energy difference between higher and lower energy level.
f: Frequency of light in the spectrum.
h: Planck's constant.
The expression indicates that the energy difference is proportional to the frequency. **(4 × 3)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(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)**

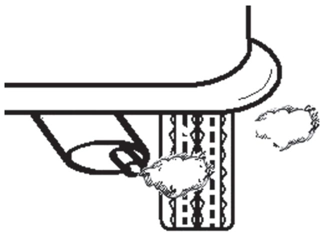
(ii) Name the alcohol produced when propanal (**C_2H_5CHO**) is reduced. **(3)**

(iii) (1) Draw the structure of the alcohol produced when propanone (**CH_3COCH_3**) is reduced. (2) To which class (primary, secondary or tertiary) of alcohols does it belong? **(6)**

(iv) (1) Which of the two compounds, propanal or propanone, would be oxidised by warm Fehling's solution?
(2) Give the name *and* structure of the organic product of the oxidation reaction. **(9)**

(v) Give **one** common use for propanone. **(3)**

(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 143g CO_2/km (i.e. the car produces 143g 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)**

(iv) If a large SUV (sports utility vehicle) with a CO_2 emission rating of 264g 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)**

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

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 <u>greenhouse gas</u> and an <u>acidic oxide</u>.

Al Gore

(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)**

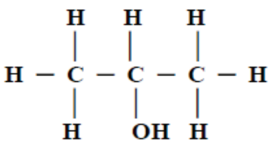
(iv) Why is recycling of aluminium metal important for the protection of the environment? **(3)**

SOLUTION

11. (a) (i) Nickel. **(4)**

(ii) Propan-1-ol. **(3)**

(iii) (1)

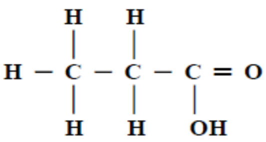


(3)

(2) Secondary alcohol. **(3)**

(iv) (1) Propanal. **(3)**

(2) Propanoic acid. **(3)**



(3)

(v) Nail varnish remover. **(3)**

(b) (i) Total mass of CO_2 produced per day: $143 \times 8 = 1144$ **(6)**

(ii) No. of moles of CO_2 produced per day: $\frac{1144}{44} = 26$ moles **(6)**

(iii) Volume occupied $26 \times 24 = 624$L (1 mole occupies 24L at room temperature and pressure). **(6)**

(iv) For SUV the total mass of CO_2: $264 \times 8 = 2112$g

No. of moles $= \frac{2112}{44} = 48$ moles

Volume occupied: $48 \times 24 = 1152$L **(4)**

Difference: $1152 - 624 = 528$L **(3)**

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(c) A (i) Greenhouse gas: Atmospheric gas that absorbs heat. **(4)**
Acidic oxide: Oxide that gives an acidic solution in water. **(3)**
(ii) Combustion, respiration, landfill. **(Any 2 × 3)**
(iii) Carbonate ions, hydrogencarbonate ions, carbonic acid. **(3 × 3)**
(iv) Limestone (calcium carbonate). **(3)**

B (i) Bauxite. **(4)**
Sodium hydroxide. **(3)**
(ii) Positive electrode: $O^{2-} - 2e^- \longrightarrow \frac{1}{2}O_2$ ← **TIP:** Formulas **(3)**, Balancing **(3)**.
Negative electrode: $Al^{3+} + 3e^- \longrightarrow Al$ ← **TIP:** Formulas **(3)**, Balancing **(3)**.
(iii) Lowers the melting point. **(3)**
(iv) Avoids litter; prevents loss of aluminium. **(Any 1 × 3)**

SECTION A

Answer at least two questions from this section.

QUESTION 1

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 500cm^3 in a volumetric flask. A burette was filled with this solution and it was then titrated against 25.0cm^3 portions of previously standardised 0.05 M iodine solution in a conical flask. The average titre was 20.0cm^3.

The equation for the titration reation is

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

(a) Sodium thiosulfate is not a <u>primary standard</u>. 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 500cm^3. **(15)**

> **TIP:** Needs five relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

(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)**

> **TIP:** Need four colour changes, each worth 3 marks.

(e) Calculate the (i) molarity of the sodium thiosulfate solution and its (ii) concentration in grams of crystalline sodium thiosulfate **($Na_2S_2O_3.5H_2O$)** per litre. **(12)**

SOLUTION

1. **(a)** Pure, stable, soluble material from which solutions of known concentration can be made. **(5 + 3)**

(b)
- Rinse the crystals from the clock glass into the beaker with deionised water.
- Stir the solutions until the crystals are dissolved.
- Transfer the solution to a volumetric flask using a funnel.
- Rinse the beaker with deionised water and transfer to the volumetric flask.
- Add deionised water until the bottom of meniscus is on the graduation mark, reading it at eye level.
- Stopper and invert several times. **(Any 5 × 3)**

> **TIP:** No marks awarded for this if 'shake' used instead of 'invert'.

(c) Potassium iodide. **(3)**

(d) Reddish brown to **(3)**
Straw yellow to **(3)**
Blue/black to **(3)**
Colourless. **(3)**

(e) (i)

I_2	S_2O_3
$V_{ox} = 25$	$V_{red} = 20$
$M_{ox} = 0.05$	$M_{red} = ?$
$n_{ox} = 1$	$n_{red} = 2$

$$\frac{V_{ox} \times M_{ox}}{n_{ox}} = \frac{V_{red} \times M_{red}}{n_{red}}$$

$$\frac{25 \times 0.05}{1} = \frac{20 \times M_{red}}{2} \textbf{ (3)}$$

$$M_{red} = 0.125 \text{ moles/L } \textbf{(3)}$$

(ii) 0.125×248 **(3)**

$= 31$g/L **(3)**

> **TIP:** Mass of $Na_2S_2O_3.5H_2O$

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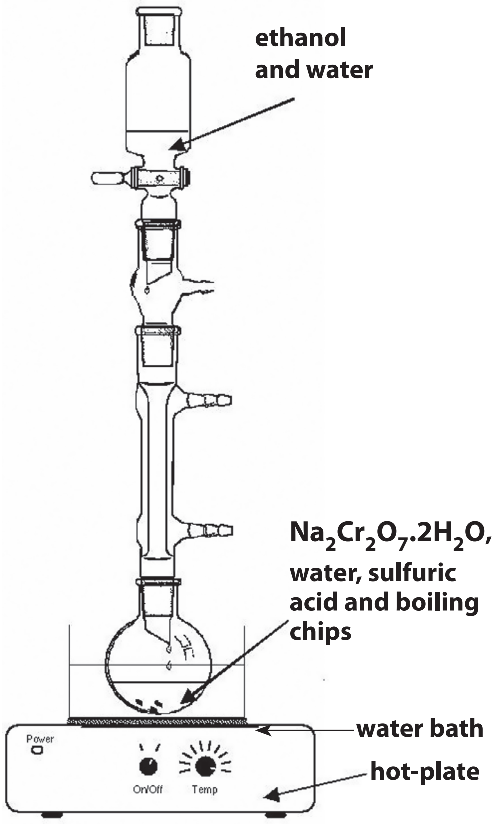
QUESTION 2

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)**

TIP: The colour change needs to be stated and the reason for the presence of each colour given.

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

TIP: You must comment on why heat is needed.

TIP: You must comment on why the mixture needed to be refluxed.

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

TIP: You need to convert amounts to moles and use equation to show ethanol is limiting.

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

TIP: The question needs two distinct points.

(f) (i) Describe your observations when a small quantity of solid sodium carbonate was added to a sample of the ethanoic acid produced.

(ii) Write a balanced chemical equation for the reaction which occurred. **(9)**

TIP: Formulas **(3)**, Balancing **(3)**.

SOLUTION

2. (a) Add the mixture dropwise. **(4)**
Cool the reaction vessel in cold water. **(4)**

(b) Orange to **(3)**
Green. **(3)**
Cr^{+6} reduced to Cr^{+3}. **(3)**

(c) Boiling the solution.
To ensure complete oxidation to ethanoic acid.
Without loss of any of the vapour. **(Any 2 × 3)**

(d) Ethanol: Need to convert volume to grams using $d = \frac{m}{V}$

$0.80 = \frac{m}{8} \rightarrow m = 6.4g$ **(3)**

Moles of ethanol: $\frac{6.4}{46} = 0.139$ moles **(3)**

Moles of dichromate: $\frac{29.8}{29.8} = 0.1$moles **(3)**

$3C_2H_5OH + 2Cr_2O_7^{2-} \rightarrow$

0.139 0.1

In a 3:2 ratio the dichromate requires 0.15 moles of ethanol. There is only 0.139 moles, therefore the ethanol is limiting and the dichromate is in excess. **(3)**

(e) By distillation. **(6)**

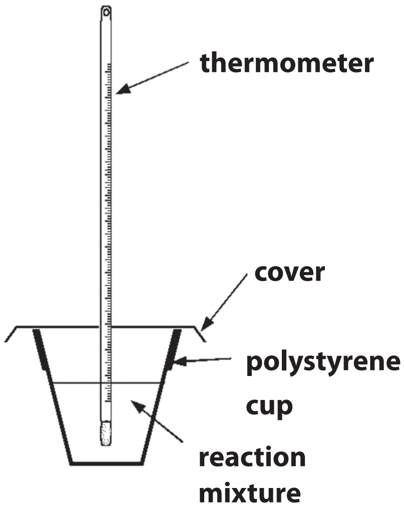
(f) (i) Fizzing as CO_2 is given off. **(3)**

(ii) $Na_2CO_3 + 2CH_3COOH \rightarrow 2CH_3COONa + H_2O + CO_2$ **(3 + 3)**

QUESTION 3

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

TIP: You need volumes and concentrations for calculations.



(a) To achieve an appreciable temperature rise during the reaction, quite concentrated solutions of acid and base, carrying the label illustrated, were used.

(i) What word describes the chemical hazard illustrated in this label?

(ii) 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)**

TIP: Starting temperature.

(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 420JK^{-1}, calculate the heat released in the experiment if a temperature rise of 6.7°C was recorded.

Hence calculate the heat of reaction for

$$NaOH + HCl \rightarrow NaCl + H_2O \qquad \textbf{(18)}$$

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

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SOLUTION

3. **(a)** (i) Corrosive. **(4)**

(ii) Wear protective clothing.
Do not allow contact with skin.
Wear eye protection. **(Any 1 × 4)**

(b) Burette. **(3)**

(c) Wait until the two solutions come to the same temperature. **(6)**
OR
Get the average temperature of the two solutions.

(d) Add solutions quickly to each other.
Without splashing.
Stir constantly.
Replace cover immediately. **(Any 3 × 3)**

(e) Polystyrene is a good insulator. **(3)**

(f) Number of molecules of acid $= \frac{Volume \times molarity}{1000}$

$= \frac{50 \times 1}{1000}$ **(3)**

$= 0.05$ mol **(3)**

Heat given out: (total heat cap.) × $(t_2 - t_1)$
420×6.7 **(3)**
= 2814J **(3)**

0.05 moles gives out 2814 J

Therefore, 1 mole $= \frac{2814}{0.05}$ **(3)**

= 56280J
So the heat of reaction = –56.28kJ/mol **(3)**

(g) Bomb calorimeter. **(3)**

SECTION B

QUESTION 4

Answer **eight** of the following items (a), (b), (c), etc. **(50)**

(a) Define *atomic (covalent) radius*.

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

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

TIP: A definition of each will do.

(d) What is meant by *heterogeneous* catalysis?

TIP: Definition.

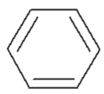
(e) How many iron atoms should be consumed daily to meet the recommended daily intake of iron in the diet of 0.014g?

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

(g) (i) Name and (ii) draw the structure of a carboxylic acid that is widely used as a food preservative.

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

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

 instead of  or 

(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?

(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.

SOLUTION

4. (a) Half the distance between the centres **(3)**
of singly bonded atoms of the same element. **(3)**

(b) Raise octane number. **(6)**

(c) *Sigma*: Head-on (end-on) overlap of orbitals. **(3)**

Pi: Lateral (sideways) overlap orbitals. **(3)**

(d) Reactants and catalyst in different phases. **(6)**

TIP: Only 3 marks awarded if 'state' used.

(e) Intake: $0.014 \div 56 = 0.00025$ **(3)**
$\times 6 \times 10^{23} = 1.5 \times 10^{20}$ **(3)**

(f) Iron (II) sulfate. **(3)**
Concentrated sulfuric acid. **(3)**

(g) (i) Ethanoic acid. **(3)**

(ii) CH_3COOH **(3)**

(h) Calculate: $\frac{21.5}{500}$ **(3)**

$\times 100 = 4.3$ **(3)**

(i) All the carbon-to-carbon bonds in benzene are identical (same length). **(6)**

(j) Absorbance is **(3)**
directly proportional to (varies directly with) concentration of substance. **(3)**

(k) (A) Hydrochloroflurocarbons (HCFCs). **(6)**

OR

(B) Sir Humphry Davy. **(6)**

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)**

TIP: You need to put in P_x, P_y, P_z.

(b) (i) Use electronegativity values (Mathematical Tables p46) to predict the type of bond expected between hydrogen and sulfur.

(ii) Write the chemical formula for hydrogen sulfide.

(iii) Use clear dot and cross diagrams to show the bonding in hydrogen sulfide. **(15)**

(iv) Would you expect the hydrogen sulfide molecule to be *linear* or *non-linear* in shape?

(v) Justify your answer. **(6)**

(c) Hydrogen sulfide has a boiling point of 212.3K and water has a boiling point of 373K.

(i) Account for the difference in the boiling points of these substances. **(6)**

(ii) Would you expect hydrogen sulfide to be soluble in water? Explain your answer. **(6)**

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SOLUTION

5. (a) The fixed energy value that the electron in the atom can have. **(5)**

Write: $1s^22s^22p^63s^23p^4$. **(3)**

Show: $3p_x^2 3p_y^1 3p_z^1$. **(3)**

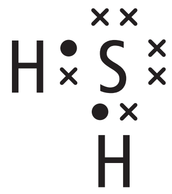
State: (i) 3 **(3)**

(ii) 9 **(3)**

(b) (i) Weakly polar. **(6)**

(ii) H_2S. **(3)**

(iii)



(6)

(iv) Non-linear. **(3)**

(v) There are non-bonding (lone) pair(s) of electrons. **(3)**

(c) (i) Hydrogen bonds in water and weak dipole–dipole forces in H_2S. **(6)**

(ii) No. **(3)**

Does not form hydrogen bonds with water. **(3)**

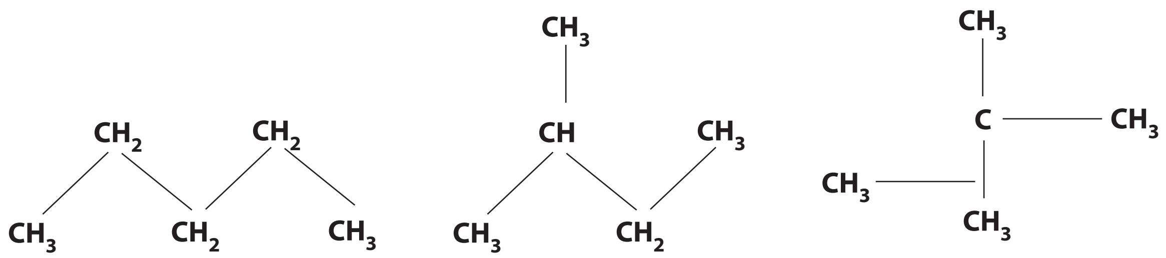
QUESTION 6

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

(a) (i) In which fraction of crude oil do pentane and its isomers occur? **(5)**

(ii) Give the systematic (IUPAC) name of each of the structural isomers of pentane shown below. **(9)**

TIP: Formulas **(3)**, Balancing **(3)**.



(iii) Which of these isomers would you predict to have the lowest octane number? **(3)**

(iv) Justify your choice in terms of the structural features of the molecules. **(6)**

(v) Write a balanced equation for the combustion of pentane (C_5H_{12}) in excess oxygen.

TIP: Formula **(3)**, Balancing **(3)**.

(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)**

(i) Explain with the aid of a labelled diagram how naphtha (b.p. approximately 100°C) is separated from gas oil (b.p. approximately 300°C) in the fractional distillation of crude oil. **(9)**

TIP: You must draw a labelled diagram and also use bullet points to explain fractional distillation.

Bitumen is a residue fraction obtained from crude oil. (ii) Give **one** use for bitumen. **(3)**

(c) (i) What is catalytic cracking?

TIP: Definition.

(ii) What is its economic importance in oil refining? **(6)**

SOLUTION

6. (a) (i) Light gasoline (petrol) fraction. **(5)**

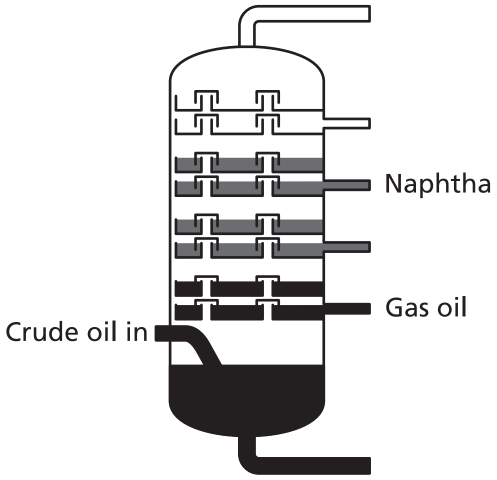
(ii) Pentane 2-methyl butane 2,2-dimethylpropane **(3 × 3)**

(iii) Pentane has the lowest octane number. **(3)**

(iv) It is a straight chain molecule. **(6)**

(v) $C_5H_{12} + 8O_2 \rightarrow 5CO_2 + 6H_2O$ (Formulas **(3)**, Balancing **(3)**.)

(b) (i) Naphta fraction has shorter chains. **(3)**



(3)

Pass vapour up the column. **(3)**
Naphta condenses (comes off) higher up the column. **(3)**

(ii) Bitumen is used in tarring or roofing or waterproofing. **(Any 1 × 3)**

(c) (i) Breaking of long chain hydrocarbon molecules into shorter molecules. **(3)**

(ii) More demand for these products. **(3)**

QUESTION 7

(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**):

TIP: Write down what each species is and then answer the specific question asked.

$$HNO_2 + H_2O \rightleftharpoons NO_2^- + H_3O^+$$ **(6)**

Distinguish between a strong acid and a weak acid. **(6)**

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

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

(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)**

TIP: Needs three relevant points worth 3 marks each. Use bullet points and put in as many points as you can remember.

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

SOLUTION

7. (a) (i) Acid is a proton donor. **(4)**

(ii) Conjugate pair is any acid–base pair that differ by 1 proton. **(4)**

$$\underset{\text{Acid}}{HNO_2} + \underset{\text{Base}}{H_2O} \Leftrightarrow \underset{\text{Conj. base}}{NO_2^-} + \underset{\text{Conj. acid}}{H_3O^+}$$ **(2 × 3)**

A strong acid is a good proton donor. **(3)**
A weak acid is a poor proton donor. **(3)**

(b) (i) $[H^+] = \sqrt{K_a \times M_a}$ **(3)**

$\sqrt{5 \times 10^{-4} \times 0.1}$ **(3)**

$= 0.007$

$pH = -\log_{10}[H^+]$

$= -\log_{10}(0.007)$

$= 2.15$ **(3)**

(ii) $pH = -\log_{10}[H^+]$

$= -\log_{10}(0.1)$ **(3)**

$= 1$ **(3)**

(c)
- Enrichment of water with nutrients, which
- Leads to rapid growth of algae.
- These algae are short lived and decay, which
- Causes the depletion of dissolved oxygen in the water. **(Any 3 × 3)**

(d) By precipitation. **(6)**

QUESTION 8

Study the reaction scheme and answer the questions which follow.

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

TIP: Draw the structure of each molecule.

(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 (i) reagent and the (ii) catalyst required to convert **C** to **B**. **(6)**

(d) (i) Draw full structural formulas for **B** and **C**. (ii) Indicate any carbon atom in either structure that has planar geometry. (iii) 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)**

TIP: Needs 3 points worth 3 marks each.
Use bullet points and put in as many points as you can remember.

(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)**

SOLUTION

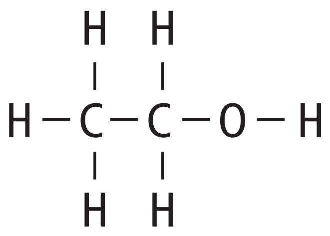
8. (a) (i) Alkenes. **(4)**

(ii) Aldehydes. **(4)**

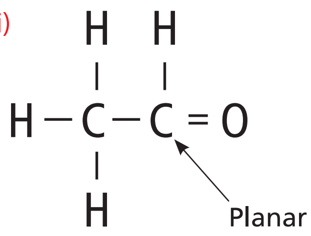
(b) The loss of a small molecule from the larger molecule. **(3)**
Leaving a double bond in the larger molecule. **(3)**

(c) (i) Reagent: Hydrogen. **(3)**
(ii) Catalyst: Nickel or palladium or platinum. **(Any 1 × 3)**

(d) (i)



(ii)



TIP: Formulas **(3+3)**, Planar **(3)**

(iii) Bonds broken: C-H and O-H **(2 × 3)**
Bond made: C=O **(3)**

(e)
- Add ethanol to Fehling's solution. **(3)**
- Place the test tube in a beaker of hot water. **(3)**
- Brick red precipitate is observed. **(3)**
- (Could also have used Tollens' reagent test)

(f) From the ingestion of alcohol. **(3)**

QUESTION 9

(a) (i) Define the *rate of a chemical reaction*.
(ii) 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 11–15mm) and 50cm^3 of 2.0M 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)**

TIP: Time on *x*-axis and mass on *y*-axis.

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) (i) Describe and (ii) explain the effect on the rate of reaction of repeating the experiment using 50cm^3 of 1.0M hydrochloric acid and the same mass of the same size marble chips. **(6)**

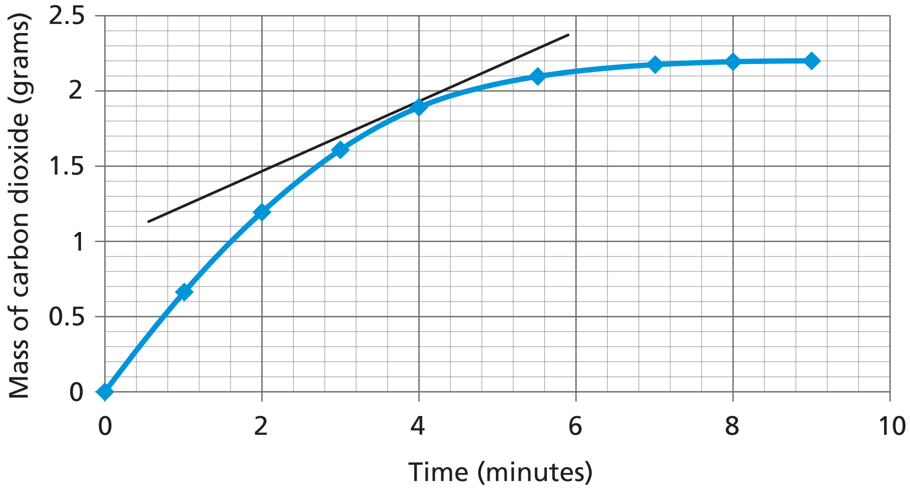
(d) Particle size has a critical effect on the rate of a chemical reaction.

(i) Mark clearly on your graph the approximate curve you would expect to plot if the experiment were repeated using 50cm^3 of 2.0M HCl and using the same mass of marble chips but this time with a diameter range of 1–5mm. **(6)**
(ii) Dust explosions present a risk in industry. Give **three** conditions necessary for a dust explosion to occur. **(9)**

SOLUTION

9. (a) (i) Change in concentration per unit time of any one reactant or product. **(4)**
(ii) Reactant(s) are used up. **(4)**

(b)



MARKS:

Labelled and scaled axes. **(3)**

All points plotted correctly. **(6)**

Curve drawn to (0, 0). **(3)**

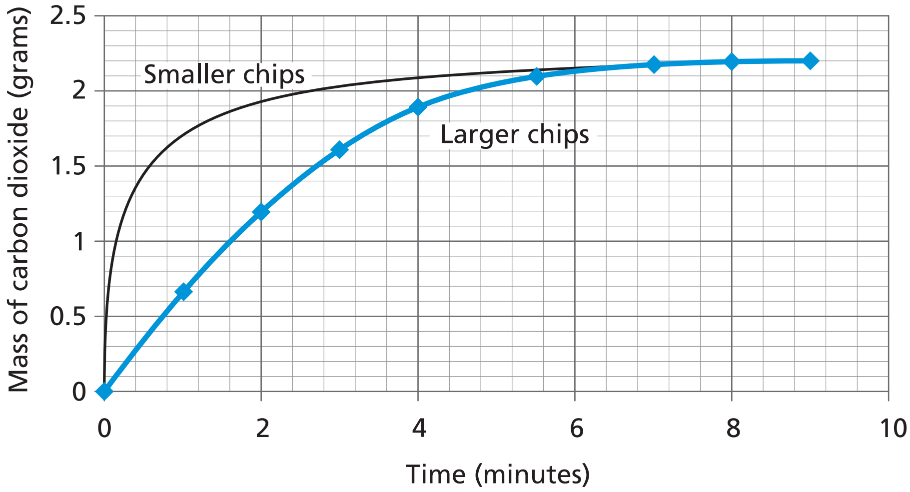
(i) 0.20–0.26g/min (slope of tangent to curve). **(6)**

(ii) 0.004–0.006mol/min (convert to moles). **(3)**

(c) (i) Slower rate of reaction. **(3)**

(ii) Acid is less concentrated. **(3)**

(d) (i)



(6)

(ii) Dryness.

Source of ignition.

Oxygen.

Enclosed space.

Combustible dust particles. **(Any 3 × 3)**

QUESTION 10

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(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)**

(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. (1) What volume does this gas occupy at a pressure of 1.01×10^5Pa and a temperature of 290K? **(9)**
(2) 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)**

(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)**

SOLUTION

10. (a) (i) $K_c = \frac{[NH_3]^2}{[N_2][H_2]^3}$ **(7)**

(ii)

	N_2	$3H_2$	$2NH_3$
Initial	3	9	0
Change	$-1x$	$-3x$	$+2x$
At equilibrium	2	6	2

(6)

$\frac{[2]^2}{[2][6]^3}$ **(3)**

= 0.009 **(3)**

(iii) The yield of ammonia would increase. **(3)**

Reaction shifts to side with the fewer number of molecules. **(3)**

(b) (i) Equal volumes of gases contain equal numbers of molecules. **(4)**

Under the same conditions of temperature and pressure. **(3)**

(ii) (1) No. of moles of $CO_2 = \frac{2000}{44} = 45.5$ **(3)**

$PV = nRT$

$1.01 \times 10^{-5} \times V = 45.5 \times 8.3 \times 290$ **(3)**

$V = 1.084\text{m}^3$ **(3)**

(2) Helium: 45.5×4 **(3)**

= 182g **(3)**

(iii) Stronger intermolecular forces. **(3)**

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(c) (i) The oxidation number decreases. **(4)**

(ii)

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

0 +2 −1 +3 **(3 + 3)**

Br goes from 0 to −1 and so is reduced, therefore it is the oxidising agent.

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

0 +4 2(+1)−2 −1 +6 4(−2) +1 **(3 + 3)**

Cl goes from 0 to −1 and so is reduced, therefore it is the oxidising agent.

$Cl_2 \quad + \quad SO_3^{2-} \quad + \quad H_2O \quad \rightarrow \quad 2Cl^- \quad + \quad SO_4^{2-} \quad + \quad 2H^+$ **(6)**

(iii) Electronegativity decreases down the group. **(3)**

QUESTION 11

Answer any **two** of the parts (a), (b) and (c). **(2 × 25)**

(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)**

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)**

$$^{210}_{84}\text{Po} \rightarrow \, ^{y}_{x}\text{Z} + \, ^{4}_{2}\text{He}$$

(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)**

(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)**

SOLUTION

11. (a) (i) Positively charged sphere **(4)**
with the electrons embedded in it. **(3)**

TIP: 'Electrons' have to be mentioned.

(ii) *Observations:*

(1) Deflection of alpha particles at large angles. **(3)**

(2) Alpha particles rebounded straight back along their own path. **(3)**

Explanation:

(1) Particles passed close to a small positive mass. **(3)**

(2) Particles collided with the small dense mass (nucleus). **(3)**

(iii) $^{210}_{84}Po \rightarrow ^{206}_{82}Pb + ^{4}_{2}He$

Pb and 82 **(3)**

206 **(3)**

(b) (i) Provides the energy for the splitting of the chlorine molecules **(4)**
into free radicals. **(3)**

(ii) Chloromethane and hydrogen chloride. **(2 × 3)**

(iii) Two methyl radicals ($CH_3\cdot$) combine to give ethane. **(6)**

(iv) Ionic addition. **(3)**

(v) Solvents, dry cleaners, paint stripper. **(Any 1 × 3)**

(c) A

(i) Respiration, combustion. **(Any 1 × 4)**

(ii) Is a measure of the greenhouse effect of a particular gas compared with carbon dioxide. **(6)**

(iii) Water, methane, CFCs. **(Any 2 × 3)**

(iv) Carbonate ions, hydrogencarbonate ions, carbonic acid. **(3 × 3)**

B

Aluminium: Metallic crystal.

Sodium chloride: Ionic crystal.

Graphite: Covalent macromolecular crystal. **(3 + 2 + 2)**

(i) The outer electrons are delocalised, which are free to move. **(6)**

(ii) Ions are attracted to the polar water molecule. **(6)**

(iii) Forces between the layers of carbon atoms are weak because of the distance between them. **(6)**

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