(a) (i) Define *atomic orbital*. **(5m)**

– region around nucleus with a high probability of finding an electron (5)

(ii) Write the electron configuration (*s*, *p*) of the copper ion (Cu^{2+}). **(6m)**

– $1s^2, 2s^2, 2p^6, 3s^2, 3p^6, (4s^0), 3d^9$ (6)

(iii) How many orbitals are occupied in a copper ion (Cu^{2+})? **(3m)** (3

(i) Define *first ionisation energy* of an element. **(2 × 3m)**

– minimum amount of energy required to remove the most loosely held electron
– from 1 mole gaseous atoms in ground state

(ii) Give **two** reasons why ionisation energy values exhibit a general decrease on going group. **(2 × 3m)** (6)

– increased shielding
– increased atomic radius / increase in number of shells

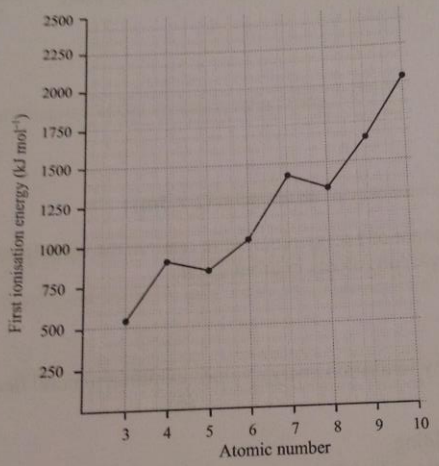
(iii) Use the changing values of ionisation energies to explain why the Group I alkali m become more active on going down the group. **(6m)**

– it is easier to remove an outer electron in a reaction

(iv) Use the values on page 80 of the *formulae and tables booklet* to draw a graph showing first ionisation energy *versus* atomic number for the elements with atomic numbers from 3 to 10 inclusive. **(4 × 3m)** (12)

– axes correctly labelled
– axes correctly scaled
– points correctly plotted
– graph drawn

** Allow broken lines in graph.
** Deduct 3m if not on graph paper.
** Award 3m if all the points except 1 are correctly plotted.



The trend across a period is for an increase in ionisation energy.
Explain why oxygen has a lower first ionisation energy than the element that precede **(2 × 3m)**

– N more stable / O less stable
– N has a half-filled p sublevel / O has a partly filled p sublevel

In an oil refinery crude oil is boiled and the vapour is passed into the bottom of a column to separate the fractions to make fuels and other products.

(*a*) Name this process of separation. **(3m)** (9)

– fractional distillation

Explain how this works in the refinery. **(2 × 3m)**

– each component has a different boiling point
– they separate / condense (as liquids) and are removed

(*b*) Petrol is mainly made from gasoline and another fraction. Name this fraction. **(3m)** (12)

– naphtha

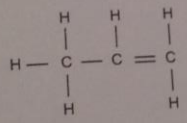
Name the process that reforms it to produce smaller fuel molecules as well as unsaturated compounds. **(3m)**

– cracking

Name the unsaturated compound C_3H_6 and draw its structural formula. **(2 × 3m)**

– propene

–



(9)

(*c*) Petrol is sold according to its *octane rating*.

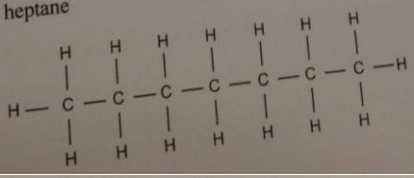
Explain why burning petrol with a low octane rating is bad for the environment. **(3m)**

– unburned hydrocarbons are bad for health / contribute to air pollution

Name a compound with an octane rating of 0 and draw its structural formula. **(2 × 3m)**

– heptane

–



LPG is a gaseous fuel produced in an oil refinery that contains propane.
Name the other component of LPG. **(4m)**

– butane

Which group of substances are added to gaseous fuels to give them a strong odour? **(4m)**

– mercaptans

Propane burns according to the following balanced equation:

$$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$$

Calculate the heat of combustion of propane given that the heats of formation of propane, dioxide and water are –103, –394 and –286 kJ mol^{-1}, respectively. **(4 × 3m)**

– heat of combustion = heat of formation of products – heat of formation of the reac
– $\Delta H = 3(-394) + 4(-286) - (-103)$
– $= -2326 + 103$
– $= -2223$ (kJ mol^{-1})

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

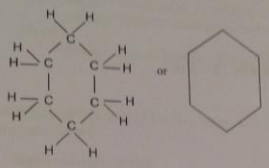
A	C_6H_{12}
B	CH_3COCH_3
C	HCOOH
D	C_2H_5OH

(*a*) Name the family (homologous series) to which **A** belongs. **(3m)** (9)

– alkane

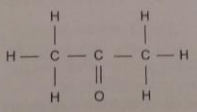
Name **A** and draw its structural formula. **(2 × 3m)**

– cyclohexane

–  or

(*b*) Name **B** and draw its molecular formula. **(2 × 3m)** (9)

– propanone

– 

Name the alcohol formed when **B** is reduced with hydrogen. **(3m)**

– propan-2-ol

(9)

(*c*) Name **C**. **(3m)**

– methanoic acid

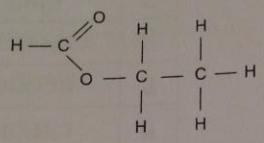
Write a balanced equation for the reaction between **C** and sodium carbonate. **(2 × 3m)**

– $2HCOOH + Na_2CO_3 \rightarrow 2HCOONa + CO_2 + H_2O$

** Formula correct (3m).
** Equation balanced (3m).

(*d*) Name the organic compound formed in the reaction between **C** and **D** and draw its structural formula. **(2 × 3m)**

– ethyl methanoate

– 

Outline the conditions required for this reaction. **(2 × 3m)**

– heat / reflux
– acid catalyst

(*e*) Compound **D** can be converted in the laboratory to a hydrocarbon gas.
Name the catalyst for this reaction. **(3m)**

– aluminium oxide / Al_2O_3

What term describes this type of reaction?

Any 1: **(3m)**
– elimination //
– dehydration

(*f*) Identify a compound in the table whose carbon atoms are all in tetrahedral geometry.

Any 1: **(5m)**
– **A** / cyclohexane / C_6H_{12} //
– **D** / ethanol / C_2H_5OH

8. (*a*) Outline **two** processes that are employed in large water treatment works to remove suspended solids from drinking water. (12)

Any 2: **(2 × 6m)**

** Named (3m), Described (3m).

– screens // *etc.*
  – to remove floating debris // *etc.*
– aluminium sulfate (alum) or other named flocculant // *etc.*
  – to flocculate (or explained) // *etc.*
– sedimentation / allow water to settle in tanks // *etc.*
  – sediment falls to / settles on bottom // *etc.*
– filtration
  – through beds of graded sand and gravel // *etc.*

(*b*) Tap water should have a pH in the range of 6 to 8. State the problem that would arise if the water is too acidic. **(3m)** (6)

– water corrodes pipes

What is added to drinking water to raise its pH? **(3m)**

– lime / calcium hydroxide

(*c*) Describe **two** other processes that involve the addition of chemicals to drinking water and explain the purpose of each. **(2 × 6m)** (12)

** Process described (3m).
** Purpose of process (3m).
– chlorination / adding chlorine of sodium hypochlorite
  – to kill disease-causing bacteria
– fluoridation / adding sodium fluorosilicate
  – to strengthen teeth (tooth enamel)

** Purpose of each process should correspond to process described.

(*d*) Temporary hardness may be caused by the presence of a number of dissolved substances including calcium hydrogencarbonate. (15)
Show by equation how calcium hydrogencarbonate is formed in a limestone region.

Any 1: **(2 × 3m)**

– $CaCO_3 + H_2O + CO_2 \rightarrow Ca(HCO_3)_2$ //
– $H_2CO_3 + CaCO_3 \rightarrow Ca(HCO_3)_2$

** Formula correct (3m).
** Equation balanced (3m).

Outline how a solution containing a hydrogencarbonate can be distinguished from a solution containing a carbonate. **(3 × 3m)**

– add magnesium sulfate (or chloride) solution
– a white precipitate forms with the carbonate
– solution remains clear with the hydrogencarbonate

(*e*) **edta** is used to measure the hardness of water. What is the full name of this reagent? **(5m)** (5)

…inetetraacetic acid

(a) The reaction between ethanoic acid and ethanol is a reversible reaction and is represented by the following equation:

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

(6)

(i) Define (*i*) *reversible reaction*, (*ii*) *equilibrium*. **(2 × 3m)**

(*i*) – the reaction that can take place in either direction / can go in both directions

(*ii*) – the rate of the forward reaction equals the rate of the reverse reaction

(*ii*) Write the equilibrium constant (K_c) expression for this equilibrium reaction. **(5m)** (5)

– $K_c = \dfrac{[CH_3COOC_2H_5][H_2O]}{[CH_3COOH][C_2H_5OH]}$

** Square brackets are essential.

(*iii*) When 3 moles of ethanoic acid (**CH_3COOH**) and 4 moles of ethanol (**C_2H_5OH**) were mixed together in a vessel and allowed to reach equilibrium it was found that the mixture contained 1 mole of ethanoic acid.

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

** Concentration of reactants found (3m).
** Concentration of products found (3m).

	CH_3COOH	C_2H_5OH	$CH_3COOC_2H_5$	H_2O
Initially	3	4		
At equilibrium	1	2	2	2

(2 × 3m)

– $K_c = \dfrac{2 \times 2}{1 \times 2}$ **(3m)**

– $= 2$ **(3m)**

(*iv*) Explain why the volume of the reaction vessel does not affect this value of K_c. **(3m)** (3)

– the same number of molecules on both sides of the equation / the volumes would cancel each other out

(*v*) What change (if any) in the value of the K_c would you expect if the quantity of ethanoic acid (**CH_3COOH**) used initially was doubled? **(3m)** (3)

– no change in K_c

State *Le Châtelier's principle*. **(2 × 3m)** (6)

– reactions at equilibrium
– oppose applied stress(es)

** If the word 'stress(es)' is replaced by particular examples (*e.g.* pressure), then expect all three (temperature, pressure and concentration) to be given.

When potassium dichromate (**$K_2Cr_2O_7.2H_2O$**) was dissolved in water an orange solution formed. The dichromate ions react with water in a reversible reaction according to the equation:

$$Cr_2O_7^{2-}\ \textbf{(orange)} + H_2O \rightleftharpoons 2CrO_4^{2-}\ \textbf{(yellow)} + 2H^+$$

(*i*) Outline how you would change the colour of the solution from orange to yellow. **(3m)**

– add some named alkali / sodium hydroxide

Explain clearly what happens during this colour change. **(2 × 3m)**

– the OH^- ions react with the H^+ ions to form H_2O
– the forward reaction predominates over the reverse reaction

(*ii*) Is the reaction between the dichromate ions and water a redox reaction? **(3m)**

– no / not a redox reaction

Justify your answer using oxidation numbers. **(3m)**

– no change in oxidation number / oxidation number is +6 on both sides

(2 × 25)

10. Answer any **two** of the parts (*a*), (*b*) and (*c*).

(*a*) (*i*) State the **two** principal purposes of chromatography that make it a valuable tool in the chemical analysis of various mixtures, for example blood and urine. **(2 × 3m)** (6)

- to separate components
- to identify components

(*ii*) Outline the principles upon which gas chromatography (GC) works. **(4 × 3m)** (12)

- the mixture is heated to evaporate it
- mobile phase is a gas
- stationary phase is a liquid
- components separated due to relative affinities for the stationary phase and the mobile phase

(*iii*) Explain why GC is unsuitable for the analysis of certain kinds of substances. **(4m)** (7)

- (GC is unsuitable) if components not volatile

Name another type of chromatography other than GC.

Any 1: **(3m)**

- paper chromatography //
- thin-layer chromatography //
- column chromatography //
- high-performance liquid chromatography / HPLC

(*b*) (*i*) Define *radioactivity*.

- emission of (alpha, beta or gamma) radiation **(3m)**
- from unstable nuclei **(4m)**

(*ii*) Radioactivity was discovered by chance in 1896.
Name the scientist who is credited with the discovery of radioactivity. **(3m)**

- (Henri) Becquerel

What effect of the radioactivity was observed by this scientist? **(3m)**

- clouding of / darkening of a photographic plate

(2 × 25)

11. Answer any **two** of the parts (*a*), (*b*) and (*c*).

(*a*) (*i*) What is meant by *empirical formula*? **(4m + 3m)** (7)

– the simplest
– whole number ratio of the atoms (in a compound)

(*ii*) Calculate the empirical formula of a compound that consists of 52.17% carbon, 13.04% hydrogen and 34.79% oxygen. **(3 × 3m)** (9)

– C: $\frac{52.17}{12} = 4.35$

H: $\frac{13.04}{1} = 13.04$

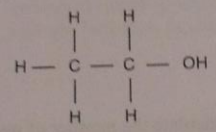
O: $\frac{34.79}{16} = 2.17$

– each number ÷2.17
– C: 2; H: 6; O: 1

(*iii*) The molecular mass of the compound in (*ii*) is 46.
Name the compound and draw its structural formula. **(3 × 3m)**

– unit mass is 24 + 6 + 16, *i.e.* 46, *i.e.* molecular formula is C_2H_6O (C_2H_5OH)
– ethanol

–



(*b*) (*i*) Define *oxidation* in terms of electron transfer. **(4m)**

– the loss of electrons

(*ii*) What is the oxidation number of S in (*i*) sodium sulfite (**Na_2SO_3**), (*ii*) sodium sulfa (**Na_2SO_4**)? **(2 × 3m)**

(*i*) – +4
(*ii*) – +6

(*iii*) When chlorine is added to an aqueous solution of sodium sulfite, the sulfite ions are oxidised to sulfate. Describe how you would demonstrate that this change has occurred. **(3 × 3m)**

(9)

- add barium chloride (Ba_2Cl_2) solution
- followed by dilute hydrochloric acid (HCl)
- precipitate remains (indicating presence of sulfate)

(*iv*) When an aqueous solution of sodium sulfate containing a few drops of universal indicator is electrolysed, the colour of the solution changes to red and a gas is formed at one of the electrodes. Show by equation the chemical change that has occurred at this electrode. **(6m)**

(6)

- $H_2O - 2e^- \rightarrow 2H^+ + \frac{1}{2}O_2$

** LHS correct: (3m).
** RHS correct: (3m).

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

A

Global warming and climate change are predicted to occur as a result of the increased release into the atmosphere of greenhouse gases, including carbon dioxide, produced by human activities.

(*i*) What is the approximate level of carbon dioxide in the earth's atmosphere: 0.04%, 0.4%, 4%? **(4m)**

(4)

- 0.04%

(*ii*) Explain how greenhouse gases can increase the earth's temperature. **(3 × 3m)**

(9)

- rays of sun's heat passes through
- earth's rays absorbed by gases
- as they are longer wavelength (earth cooler than sun)

(*iii*) Identify **two** gases that have a stronger greenhouse effect than carbon dioxide.

(1

Any 2: **(2 × 3m)**

- methane / CH_4 //
- N_2O //
- chlorofluorocarbons / CFCs

Give a human activity that is a source for each gas.

Any 2: **(2 × 3m)**

– methane / CH_4 – farming // emissions from landfills // *etc.*

– nitrous oxide / N_2O – farming // use of aerosols // wastewater / sewage treatment // *etc.*

– chlorofluorocarbons / CFCs – use of aerosols // use of refrigerants // *etc.*

or

B (4)

(*i*) State **one** property of transition elements.

Any 1: **(4m)**

– from coloured compounds //
– have a number of different oxidation states / variable valencies //
– have a catalytic activity

(*ii*) Coke plays an important role in reducing iron oxide, Fe_2O_3 (haematite), to iron in a blast furnace. Show by equations **two** roles for coke in this process. (12)

To melt the mixture

Any 1: **(6m)**

– $C + O_2 \rightarrow CO_2$ //
– $C + ½O_2 \rightarrow CO$ //

** Right hand side correct: (3m).
** Left hand side correct: (3m).

To reduce the ore **(6m)**

– $3C + Fe_2O_3 \rightarrow 2Fe + 3CO$

** Right hand side correct: (3m).
** Left hand side correct: (3m).

(*iii*) What is the function of limestone in the blast furnace? **(2 × 3m)** (6)

– to form CaO (lime)
– to remove impurities

(*iv*) Name the metal that is added to steel to make stainless steel. **(3m)**

– chromium