YEAR 11 CHEMISTRY
UNITS 1 & 2
TRIAL EXAM 2
MARKING GUIDE

Section One: Multiple-choice **(50 marks)**

1	a ☐ b ☐ c ■ d ☐
2	a ☐ b ■ c ☐ d ☐
3	a ☐ b ☐ c ■ d ☐
4	a ☐ b ■ c ☐ d ☐
5	a ☐ b ☐ c ☐ d ■

11	a ☐ b ■ c ☐ d ☐
12	a ☐ b ☐ c ☐ d ■
13	a ☐ b ☐ c ■ d ☐
14	a ■ b ☐ c ☐ d ☐
15	a ☐ b ■ c ☐ d ☐

21	a ☐ b ■ c ☐ d ☐
22	a ☐ b ☐ c ☐ d ■
23	a ☐ b ■ c ☐ d ☐
24	a ☐ b ☐ c ☐ d ■
25	a ☐ b ■ c ☐ d ☐

6	a ■ b ☐ c ☐ d ☐
7	a ☐ b ■ c ☐ d ☐
8	a ☐ b ☐ c ☐ d ■
9	a ☐ b ■ c ☐ d ☐
10	a ☐ b ■ c ☐ d ☐

16	a ☐ b ☐ c ■ d ☐
17	a ☐ b ■ c ☐ d ☐
18	a ☐ b ☐ c ☐ d ■
19	a ■ b ☐ c ☐ d ☐
20	a ■ b ☐ c ☐ d ☐

(2 marks per question)

Section Two: Short answer 35% (70 marks)

Question 26 (6 marks)

Cobalt is a silver metal which is malleable and ductile. Chlorine is a pale yellow-green gas at room temperature. However, when these two elements combine, they produce brittle crystals of blue cobalt(II) chloride. Explain these differences in physical properties, in terms of the structure and bonding of the three substances.

- **Cobalt has metallic bonding, which is characterised by non-directional bonding between the delocalised sea of electrons and the positive metal ions. This accounts for its malleability and ductility. (2)**

- **Chlorine is a covalent molecule, with weak intermolecular forces. This accounts for its low boiling point and therefore why it is a gas at room temperature. (2)**

- **Cobalt(II) chloride is an ionic substance, characterised by a rigid 3D lattice made up of cations and anions. If the ordered arrangement of ions is disrupted, like charges will repel and the substance will shatter, hence its brittleness. (2)**

Question 27 **(8 marks)**

Dry ice is the name given to solid carbon dioxide (CO_2). It is often used in theatre productions, because at room temperature dry ice will 'sublime' or turn from the solid state directly into a gas. This creates white 'clouds' that can be used for various special effects.

(a) A small piece of dry ice was placed in a sealed metal container at room temperature. Explain, in terms of the kinetic theory, why the pressure inside the container would have changed once the piece of dry ice has sublimed and the container had returned to room temperature. (3 marks)

- **sublimation results in many more gas particles within the container**
- **these gas particles will therefore collide much more frequently with each other and with the walls of the container**
- **a greater number of collisions results in a greater pressure**

Under conditions of high pressure and/or low temperature, gases will not behave as 'ideal gases'.

(b) State one example of how gases vary from the expected behaviour of ideal gases. Explain why this variation occurs. (2 marks)

- **the space the gas particles occupy becomes significant, OR**
  the forces of attraction between the particles becomes significant

- **the reason for these variations is the proximity of the gas particles (due to either the high pressure or the low temperature), and this becomes most significant at the point where liquefaction is close to occurring**

(c) A 3.75 L cylinder was storing 5.28 g of a gas at STP. Could the identity of this gas be carbon dioxide? Explain, showing all working. (3 marks)

n(gas)	**=**	**V / 22.71**
	=	**3.75 / 22.71**
	=	**0.165125 mol**
M(gas)	**=**	**m / n**
	=	**5.28 / 0.165125**
	=	**32.0 g mol^{-1}**

No, it could not be CO_2 as $M(CO_2)$ = 44.01 g mol^{-1}

Question 28 **(13 marks)**

Consider the solubility information given in the table below.

	Solubility in water (g per 100 mL)
Potassium nitrate (KNO_3)	32.0
Ammonium nitrate (NH_4NO_3)	150
Potassium phosphate (K_3PO_4)	90.0

(a) Classify the solutions below as 'saturated', 'unsaturated' or 'supersaturated'. Explain your reasoning. (5 marks)

(i) 216 g of K_3PO_4 was dissolved in 240 mL of water.

- **saturated**
- **90 x 2.4 = 216 g i.e. 216 g can dissolve in 240 mL of water**

(ii) 0.375 mol of KNO_3 was dissolved in 170 mL of water.

- **unsaturated**
- **m(KNO_3 dissolved in 170 mL) = nM = 0.375 x 101.11 = 37.9 g**
- **32 x 1.7 = 54.4 g i.e. max of 54.4 g can dissolve in 170 mL of water**

(b) A saturated solution of NH_4NO_3 was prepared. Describe how this could be used to form a supersaturated solution. (3 marks)

- **the solution would be heated**
- **then more NH_4NO_3 solute would be dissolved**
- **then the solution would be cooled back to original temp**

The two solutions described in part (a) were mixed together.

(c) Calculate the final concentration (in mol L^{-1}) of potassium ions (K^+) in the resulting solution. (5 marks)

n(K_3PO_4) = m/M
= 216 / 212.27
= 1.017572 mol

n(K^+ from K_3PO_4) = 3 x n(K_3PO_4)
= 3 x 1.017572
= 3.052716 mol

n(K^+ from KNO_3) = n(KNO_3)
= 0.375 mol

n(K^+ total) = 3.052716 + 0.375
= 3.427716 mol

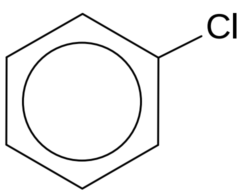
c(K^+ total) = n(total) / V(total)
= 3.427716 / 0.410
= 8.36028 mol L^{-1}
= 8.36 mol L^{-1} (3sf)

Question 29 **(7 marks)**

Organic compounds can undergo many different types of reactions.

(a) Complete the reaction below by adding the inorganic reactant and drawing the structural diagram for the organic product formed. (2 marks)

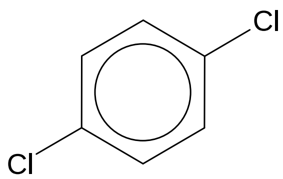
Diagram:



Name: chlorobenzene

+ **Cl_2** $\xrightarrow{AlCl_3}$

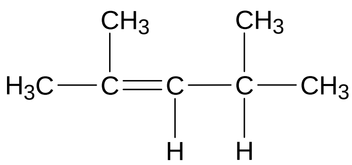
Diagram:



Name: 1,4-dichlorobenzene

(b) Complete the reaction below by giving the IUPAC name for the organic reactant and the structural diagram and IUPAC name for the organic product formed. (3 marks)

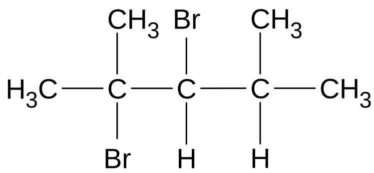
Diagram:



Name:
2,4-dimethylpent-2-ene

+ **Br_2** $\longrightarrow$

Diagram:



Name: 2,3-dibromo-2,4-dimethylpentane

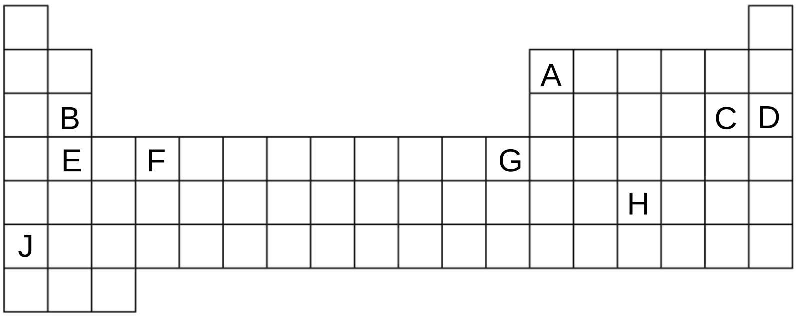
(c) Name the type of reaction occurring in; (2 marks)

(a) substitution

(b) addition / halogenation

Question 30 **(10 marks)**

Consider the elements labelled A-J on the periodic table below.



(a) Which two (2) elements are likely to have the most similar properties? (1 mark)

B and E

(b) An atom was found to have 20 protons, 22 neutrons and 20 electrons. Which of the above elements would have the same chemical properties as this atom? Explain. (2 marks)

E
They are isotopes, same number of protons & electrons = same chemical properties

(c) Which element above would have the; (3 marks)

(i) highest ionisation energy? **D**

(ii) largest atomic radius? **J**

(iii) highest electronegativity? **C**

(d) Chloride salts of F and G were found. Explain how a flame test works and how this test could be used to distinguish and identify the compounds. (4 marks)

- **a flame test could be done, where a wire loop was dipped into the 2 salts and then placed in a Bunsen burner flame**
- **the electron(s) within the cations absorb some of the heat energy and jump up to a higher energy level / electron shell further from the nucleus (this is an ‘excited’ atom)**
- **when the electrons move back down to their original energy levels/shells (this is a ‘ground state’ atom) they emit this absorbed energy as a photon, which can sometimes be seen as visible light**
- **different elements have slightly different electron energy levels, therefore the colours emitted can be different, allowing the metal cations to be distinguished**

Question 31 **(6 marks)**

Most modern cars are powered by an engine with a 4-stroke combustion cycle. The purpose of each stroke is described below.

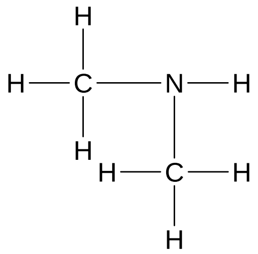
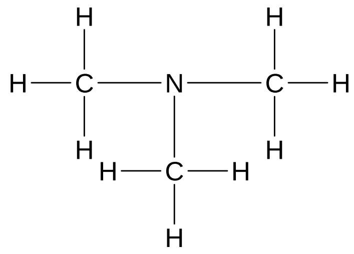
1. Intake stroke - the fuel is injected in as a fine mist, where it mixes with air
2. Compression stroke - the fuel/air mixture is compressed into a small volume
3. Combustion stroke - a spark plug ignites the fuel/air mixture, which explodes
4. Exhaust stroke - exhaust fumes leave through the valve

Explain, in terms of the collision theory, how each of the conditions described in **stroke 1, 2 and 3** affect the rate of reaction between the fuel and the air.

- **The fuel being injected in as a fine mist increases the surface area of the fuel. This allows more collisions to occur and therefore a faster reaction rate. (2)**
- **The fuel/air being compressed into a small volume increases the concentration of the reactants / partial pressure of each gas. This allows more collisions to occur and therefore a faster reaction rate. (2)**
- **The ignition increases the temperature of the reactants, which increases the average kinetic energy of the particles. A greater proportion of reactants now have enough energy to overcome the activation energy barrier, which leads to a faster reaction rate. (2)**

Question 32 **(7 marks)**

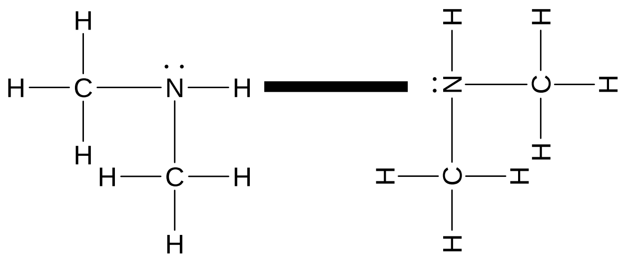
Consider the information given in the table below.

Dimethylamine	Trimethylamine
	
Boiling point 8 °C	Boiling point -3 °C

(a) Dimethylamine has the ability to form hydrogen bonds. Explain in detail how hydrogen bonds form and draw a diagram showing these bonds in dimethylamine. (4 marks)

For a hydrogen bond to form a molecule must have;

- **an H-F, H-O or H-N covalent bond**
- **a non-bonding pair of electrons**
- **the hydrogen bonds form between the hydrogen of the H-F/H-O/H-N bond and the non-bonding electron pair on the neighbouring molecule**
-



(b) Explain why trimethylamine has the stronger dispersion forces, but dimethylamine has the higher boiling point. (3 marks)

- **trimethylamine has stronger dispersion forces because it has a larger molar mass / greater total number of electrons / bigger size**
- **however these are not strong enough to compensate for the added strength of the hydrogen bonding present in dimethylamine**
- **therefore dimethylamine has overall the stronger intermolecular forces and therefore the higher boiling point**

Question 33 **(8 marks)**

When scientists are looking for other planets that might support life, they search for those that may have liquid water. Water is one of the main reasons that life can exist on planet Earth.

One of the special properties of water is that its solid form (ice) is less dense than its liquid form.

(a) Explain this property in terms of the structure and bonding present in water, and give an example of how this property of water is essential to the survival of many aquatic life forms found on Earth. (4 marks)

- **water has very strong hydrogen bonds between its molecules**
- **when freezing occurs, the molecules of water push further away from each other so that the hydrogen bonds can form the rigid, ordered structure of ice**
- **because the water molecules are now further apart than they were in the liquid state, ice has a lower density than water**
- **this property allows aquatic organisms to survive because in cold climates, lakes, rivers and oceans will freeze from the top down, allowing organisms living in the water beneath to survive**

Water that can be used for drinking is known as 'potable' water. In Perth, most of the potable water comes from groundwater or the ocean.

(b) Briefly describe 2 of the processes that may be required to treat these sources of water before they are of suitable quality to join our water supply. (4 marks)

Any two of the following processes; (1) naming process, (1) brief description

Groundwater

- **Aeration** **- remove dissolved noxious gases**
- **Chlorination** **- oxidise contaminants**
- **Clarification/Precipitation** **- clump solid particles together for removal**
- **Filtration** **- remove solid particles**

Seawater

- **Distillation** **- remove all contaminants**
- **Desalination** **- reverse osmosis to purify water**

Both

- **Disinfection** **- kill bacteria and viruses**
- **Fluoridation** **- dental benefits**

Question 34 **(5 marks)**

The equation below represents the reaction between solid iron (Fe) and hypochlorous acid (HClO).

$$6\ HClO(aq) + 6\ H^{+}(aq) + 2\ Fe(s) \rightarrow 3\ Cl_2(g) + 6\ H_2O(l) + 2\ Fe^{3+}(aq)$$

A piece of iron was placed in a solution of 1.53 mol L^{-1} hypochlorous acid. The reaction was allowed to go to completion and at the end all of the solid iron had reacted. If 1.48 L of Cl_2 was produced at STP;

(a) Calculate the volume of HClO that would have been required for the reaction to take place. (3 marks)

$n(Cl_2)$ = V / 22.71
= 1.48 / 22.71
= 0.0651695 mol

n(HClO) = 2 x $n(Cl_2)$
= 2 x 0.0651695
= 0.130339 mol

V(HClO) = n / c
= 0.130339 / 1.53
= 0.0851889 L
= 0.0852 L OR 85.2 mL (3sf)

(b) Calculate the mass of iron that must have been present. (2 marks)

n(Fe) = $n(Cl_2)$ x 2/3
= 0.0651695 x 2/3
= 0.04344635 mol

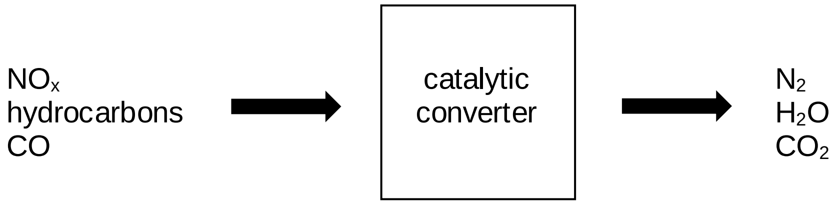
m(Fe) = nM
= 0.04344635 x 55.85
= 2.42648 g
= 2.43 g (3sf)

End of Section Two

Section Three: Extended answer 40% (80 marks)

Question 35 **(16 marks)**

The catalytic converter in a car takes in the undesirable gases produced by the combustion of petrol, such as carbon monoxide and various nitrogen oxides, and converts them into less harmful gases such as carbon dioxide, nitrogen gas and water. The less harmful gases are released into the atmosphere as we drive.



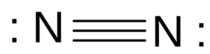
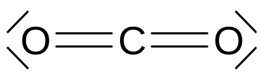
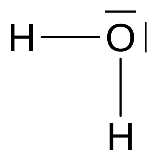
Metals such as platinum, palladium and rhodium are used as the catalyst in a catalytic converter.

(a) Explain what a catalyst is and describe its effect on the rate of a reaction. (3 marks)

- **a catalyst is a substance that increases the rate of the reaction without being used up in the reaction**
- **it functions by providing an alternate reaction pathway with a lower activation energy**
- **therefore a greater proportion of reactant particles have enough energy to overcome the activation energy barrier**

The table below shows the major gaseous products to exit a catalytic converter.

(b) Complete this table by drawing the structural formula for each of the three gases, representing all valence shell electron pairs either as : or –. In addition, state the shape of the molecule, and indicate whether or not the molecule contains polar bonds or is a polar molecule. (6 marks)

	Structural diagram	**Shape**	**Polar bonds ('yes' or 'no')**	**Polar molecule ('yes' or 'no')**
N_2		**linear**	**no**	**no**
CO_2		**linear**	**yes**	**no**
H_2O		**v-shaped / bent**	**yes**	**yes**

(-1 mark per mistake)

A sample of exhaust fumes from a car was analysed by gas chromatography (GC) to determine the composition of the fumes and assess the effectiveness of the catalytic converter.

(c) Briefly describe the principles of gas chromatography and state one reason why GC may have been chosen over other forms of chromatography to perform the analysis in this situation. (4 marks)

- **gas chromatography involves passing a sample of gas through a thin tube which is packed with an inert substance (such as silica) coated in a viscous non-volatile liquid**
- **an inert carrier gas such as helium acts as the mobile phase and moves the gas through the chromatography column where the various gas components move at different speeds as they interact with the stationary phase**
- **the gases separate based on their size/molar mass as well as their polarity and can be identified via their retention times**
- **GC works best for separating gaseous mixtures or mixtures that can easily be vaporised, which is why it is suitable for analysing car fumes**

(d) Elaborate on the information provided by this data, in terms of the composition of the car exhaust fumes and the effectiveness of the catalytic converter. (3 marks)

- **the car exhaust fumes contain the same nitrogen levels as an efficiently functioning catalytic converter**
- **whilst all of the methane has been removed by the converter, a small amount of carbon monoxide is still present in the exhaust fumes, however this is greatly reduced from the levels seen without a catalytic converter**
- **the amount of carbon dioxide is comparable to, although slightly lower than, an efficiently functioning converter, presumably due to the small amount of carbon monoxide still present in the exhaust fume mixture**

Question 36 **(15 marks)**

Carbon is the basis of all life on Earth. It is the element upon which DNA, proteins and all other organic compounds are based. The field of 'organic chemistry' is dedicated entirely to those substances containing a carbon backbone. In addition to this, carbon is found in many inorganic compounds such as carbon dioxide, limestone and baking soda. Pure carbon exists in several different forms such as diamond, graphite, buckyballs and carbon nanotubes.

(a) The two most common allotropes of carbon are diamond and graphite. What is an allotrope? (1 mark)

- different structural arrangements of the same element

Diamond possesses all the typical properties of a covalent network substance.

(b) Briefly outline and explain these properties in terms of the structure and bonding present in diamond. (4 marks)

- **every carbon atom in diamond is covalently bonded to 4 other carbon atoms**
- **this bonding is extremely strong and extends throughout the entire 3D interconnected network**
- **this results in such properties as very high melting and boiling point, strong, hard, brittle and inert**
- **the lack of mobile charge explains diamonds inability to conduct electricity in any state**

Graphite has some properties that are **not** typical of covalent network substances.

(c) Briefly outline and explain these differences in terms of the structure and bonding present in graphite. (3 marks)

- **every carbon atom in graphite is only bonded to 3 other carbons in a 2D network 'graphene sheet'**
- **the fourth valence electron of each carbon atom is delocalised and forms layers of delocalised charge between the graphene sheets**
- **this results in the conductive properties of graphite and the softness of the substance in comparison with diamond**

A third allotrope of carbon are the fullerenes. These structures come in many different shapes, forms and sizes. One type of fullerene is the carbon nanotube (CNT). Carbon nanotubes have a similar structure to graphite and are an example of a 'nanomaterial'. Due to the small particle size, it is often stated that nanomaterials have properties that differ from the bulk material.

(d) What are 'nanomaterials'? Give one example of how the properties of a nanomaterial are different from the bulk material from which they are formed. (2 marks)

- **nanomaterials are substances which contain particles in the size range of 1-100 nanometres**
- **any correct example (e.g. transparency of ZnO in sunscreen when bulk material is white, the different colour of many compounds i.e. gold when in nanoparticle form compared to their bulk form, the variable conductive properties of carbon nanotubes when compared with bulk carbon… etc)**

The area of 'nanotechnology' is relatively new and most research regarding nanomaterials is still in its infancy. Regulations are being developed to guide our research and use of these materials.

(e) What sort of risks may be associated with nanomaterials? (1 mark)

- **any correct example (e.g. unknown health effects due to small particle size, unrestricted experimentation and/or use of nanomaterials in common products such as cosmetics needs to be examined and/or communicated to the consumer, what is the effect of these small particles at the cellular level given that they can be absorbed more quickly into our bodies… etc)**

A sample of extra-terrestrial carbon nanotube was found on a meteorite that had fallen in the desert in central Australia. The sample was analysed by mass spectrometry to determine its isotopic composition and therefore calculate the relative atomic mass of the carbon comprising it.

(f) Define 'relative atomic mass' and explain the relationship between the isotopes of an element and its relative atomic mass. (2 marks)

- **relative atomic mass is the mass of an atom compared to 1/12th the mass of a carbon-12 atom**
- **the relative atomic mass of an element is calculated as a weighted average of all the naturally occurring isotopes of that element**

The following data was obtained from the mass spectrometer.

Isotope	Relative atomic mass	Percent abundance
^{12}C	12.000 u	93.41%
^{13}C	13.003 u	6.59%

(g) Use the data above to calculate the relative atomic mass of the extra-terrestrial carbon sample. (2 marks)

$$\mathbf{Ar = \frac{(12.000 \times 93.41) + (13.003 \times 6.59)}{100}}$$

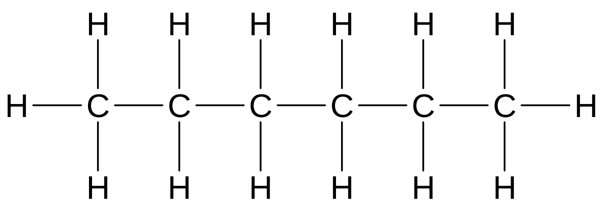
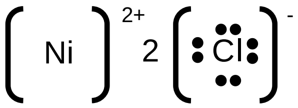
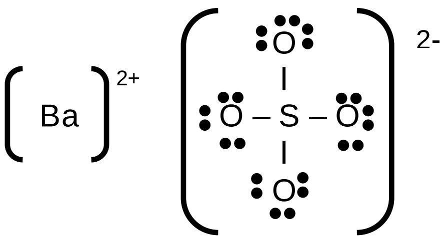
$$\mathbf{= 12.07}$$

Question 37 **(18 marks)**

A group of chemistry students were given the task of separating a mixture into its individual components. They were given a jar with four different compounds mixed together. The four components of the mixture were as follows;

- 50 mL of hexane
- 50 mL of water
- 0.5 g of nickel(II) chloride, and
- 0.5 g of barium sulfate.

(a) Draw the structural formula for three of the relevant compounds, representing all valence shell electron pairs either as : or – . (4 marks)

	Structural Formula / Lewis Structure / Electron Dot Diagram
Hexane (C_6H_{14})	
Nickel chloride ($NiCl_2$)	
Barium sulfate ($BaSO_4$)	

(b) Explain why nickel(II) chloride is soluble in water, but hexane is not. (6 marks)

- **water is a highly polar substance with hydrogen bonding as its predominant IMF**
- **hexane is a non-polar substance with only dispersion forces present between molecules**
- **therefore they are not soluble as the intermolecular forces of water and hexane are not similar enough to allow mixing to occur, there are no new forces that can form between the water and hexane molecules**

- **nickel chloride is a soluble ionic substance which dissociates in water to form the charged Ni^{2+} and Cl^- ions**
- **because water is highly polar, the negative (δ^-) poles of the water molecules will be attracted to the positive cation and the positive (δ^+) poles of the water molecules will be attracted to the negative anion**
- **new ion-dipole forces are formed between the water molecules and the ions, which allows nickel chloride to remain dissolved in water**

(marks may also be awarded for representing ion-dipole forces in a diagram rather than words)

(c) Calculate the concentration of chloride ions (Cl^-) in the aqueous layer of the mixture. (3 marks)

$n(NiCl_2)$ = m/M
= 0.5 / 129.59
= 0.00385832 mol

$n(Cl^-)$ = 2 x $n(NiCl_2)$
= 0.007716645 mol

$c(Cl^-)$ = n/V
= 0.007716645 / 0.050
= 0.154333 mol L^{-1}
= 0.154 mol L^{-1} (3sf)

(d) Explain how you could separate the mixture to produce pure samples of each of the four original compounds. (5 marks)

- **filter the mixture to remove the $BaSO_4$**
- **the $BaSO_4$ would be the residue (wash and dry to ensure pure $BaSO_4$); the other three substances would be found in the filtrate**
- **use a separating funnel / decant the mixture to remove the hexane layer**
- **use distillation apparatus to separate the nickel chloride from the water**
- **water would boil, condense and appear as the distillate; green crystals of nickel chloride would remain in the distillation flask**

(marks may be awarded for diagrams; some steps may be in different order)

Question 38 **(14 marks)**

A chemist was preparing for his next experiment by organising and labelling all his bottles of solutions. He had five bottles to go when the fire alarm went off for a practice safety drill. When he got back to his bench later he found five bottles, each containing a clear colourless liquid. Next to these bottles were the remaining five labels;

Barium hydroxide	Sodium chloride	Ethanoic acid
$Ba(OH)_2$ 0.25 mol L^{-1}	NaCl 0.25 mol L^{-1}	CH_3COOH 0.25 mol L^{-1}

Hydrochloric acid	Sodium hydroxide
HCl 0.25 mol L^{-1}	NaOH 0.25 mol L^{-1}

He set about identifying each solution so that he could finish labelling them. He began by adding a few drops of sulfuric acid to a small sample of each. This test allowed him to identify the $Ba(OH)_2$ solution straight away.

(a) What observation would he have made to allow this identification? Write the ionic equation for the reaction that could have taken place in the test tube containing $Ba(OH)_2$.
(2 marks)

- **white precipitate forming**
- **$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$**

He then added some powdered ammonium chloride (NH_4Cl) to a new sample of the remaining four unidentified solutions. Bubbles were observed to form with **one** of the unknown solutions and an unpleasant, pungent smelling gas was produced.

(b) Identify this solution and write the ionic equation for the reaction that was occurring.
(2 marks)

- **NaOH, sodium hydroxide solution**
- **$NH_4Cl(s) + OH^-(aq) \rightarrow NH_3(g) + H_2O(l) + Cl^-(aq)$**

The gas produced by the reaction in part (b) was collected and dissolved in a sample of distilled water.

(c) Describe the expected observations if litmus indicator was added to the water sample once the gas had dissolved and write an equation that supports these observations. (2 marks)

- **litmus would turn blue (due to basic ammonia solution)**
- **$NH_3(g) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$**

Universal indicator was then added to new samples of the remaining three unidentified solutions.

(d) Explain how an indicator works and describe how this test would allow **clear** identification of **one** of the substances. (3 marks)

- **an indicator is a substance that changes colour depending on the pH of the solution**
- **two of the remaining solutions (HCl and CH_3COOH) are acidic and so would have appeared red/pink/orange in universal indicator**
- **NaCl is neutral and would have appeared green in universal indicator, allowing it to be identified**

A piece of zinc metal was added to the final two solutions. In one solution, a fast reaction was seen, with much effervescence (bubbles). The other test tube also showed some effervescence but at a much slower rate.

(e) Explain in detail why a difference in reaction rate was observed between these two solutions and how this observation allowed the chemist to identify and distinguish these two solutions from one another. (5 marks)

The two remaining solutions were;

- **HCl which is a strong acid that will completely ionise in solution, and**
- **CH_3COOH which is a weak acid which will only partially ionise**
- **Therefore a much greater number/concentration of H^+ ions are present in the strong acid**
- **This will result in a much higher number of collisions between reactant particles**
- **Therefore the reaction rate will be much faster with the strong acid (HCl), allowing the chemist to distinguish the HCl and CH_3COOH**

Question 39 **(17 marks)**

Bioethanol is the same compound as ethanol (C_2H_5OH) but refers to ethanol that has been produced from 'biomass', which is a renewable resource. Ethanol is a useful fuel and combusts according to the following equation;

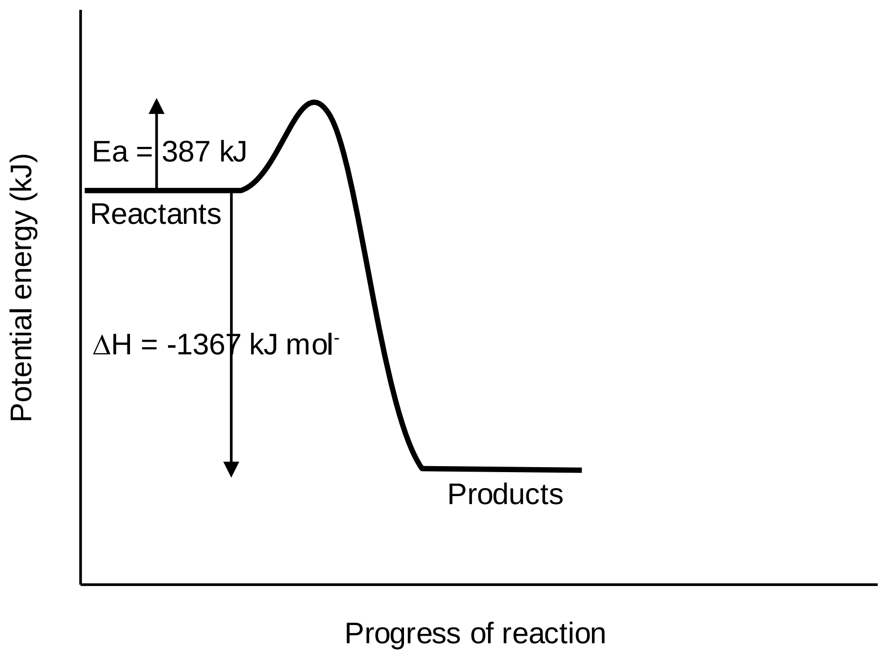
$$C_2H_5OH(l) \ + \ 3\ O_2(g) \ \rightarrow \ 2\ CO_2(g) \ + \ 3\ H_2O(l) \ + \ 1367\ kJ$$

(a) Explain briefly how bioethanol is produced. (2 marks)

- **it is produced via fermentation of plant sugars (which can be obtained from many sources such as crop waste)**
- **the reaction is catalysed by the enzymes in yeast**

If the activation energy for the combustion reaction above is 387 kJ;

(b) Draw a fully labelled energy profile diagram, to scale, for the combustion of ethanol. (4 marks)



(c) Explain how the Law of Conservation of Energy applies to your energy profile diagram. (2 marks)

- **the negative ΔH shows that the products have less enthalpy energy than the reactants, however this energy has not been lost but rather converted (to kinetic energy) and released as heat energy, ensuring that the total amount of energy in the system is the same and the Law of Conservation of Energy has been upheld**

Octane (C_8H_{18}) is a hydrocarbon fuel, which is obtained from the fractional distillation of crude oil. Unlike bioethanol it is a non-renewable resource. Octane and its many structural isomers can be found as components of the petrol we use to power our cars.

(d) Briefly describe the composition of petrol. (2 marks)

- **petrol is a mixture of hydrocarbons**
- **typically with 4-12 carbons in their structure**

The activation energy for the combustion of octane is substantially higher than the activation energy for the combustion of ethanol.

(e) What information does this give you about ethanol and octane? (2 marks)

- **activation energy often indicates how quickly / easily a reaction will take place**
- **this would suggest that the combustion of octane requires the breaking of more or stronger bonds than the combustion of ethanol**

The equation representing the combustion of octane is shown below. The enthalpy change for the combustion is -5470 kJ mol^{-1} of octane.

$$2\ C_8H_{18}(l) \ + \ 25\ O_2(g) \ \rightarrow \ 16\ CO_2(g) \ + \ 18\ H_2O(g)$$

(f) If 1.55 kg of octane was burnt, calculate the amount of heat energy released **and** the volume of carbon dioxide produced at STP. (5 marks)

$n(C_8H_{18})$ = m/M
= 1550 / 114.224
= 13.5698277 mol

E(heat) = 5470 x $n(C_8H_{18})$
= 5470 x 13.5698277
= 74226.96 kJ
= 7.42 x 10^4 kJ OR 74.2 MJ (3sf)

$n(CO_2)$ = 8 x $n(C_8H_{18})$
= 8 x 13.5698277
= 108.5586 mol

$V(CO_2)$ = 22.71n
= 22.71 x 108.5586
= 2465.366 L
= 2.47 x 10^3 L OR 2.47 kL (3sf)

End of questions