



Methodist Ladies' College Semester 1, 2015

ATAR CHEMISTRY

Solutions

Section One: Multiple-choice

25% (40 Marks)

1	a	6	c	11	b	16	b
2	b	7	a	12	c	17	d
3	d	8	a	13	c	18	b
4	a	9	d	14	c	19	d
5	c	10	b	15	d	20	d

Section Two: Short answer

45% (70 Marks)

Question 21

(7 marks)

Complete the table below by naming or writing the chemical formulae of each substance.

Name	Formula
phosphorous pentachloride	PCl_5
caesium permanganate	CsMnO_4
iron(III) carbonate	$\text{Fe}_2(\text{CO}_3)_3$
cobalt dihydrogenphosphate	$\text{Co}(\text{H}_2\text{PO}_4)_2$
selenium dioxide	SeO_2
aluminium oxalate	$\text{Al}_2(\text{C}_2\text{O}_4)_3$
chromium sulfite chromium(III) sulfite	$\text{Cr}_2(\text{SO}_3)_3$

Question 22

(6 marks)

Complete the following table.

Use the periodic table on the data sheet to determine some of your answers.

Symbol	Atomic No.	Electrons	Protons	Neutrons	Mass number
H	1	1	1	2	3
Mg^{2+}	12	10	12	12	24
$^{20}\text{F}^-$	9	10	9	11	20

Question 23

(14 marks)

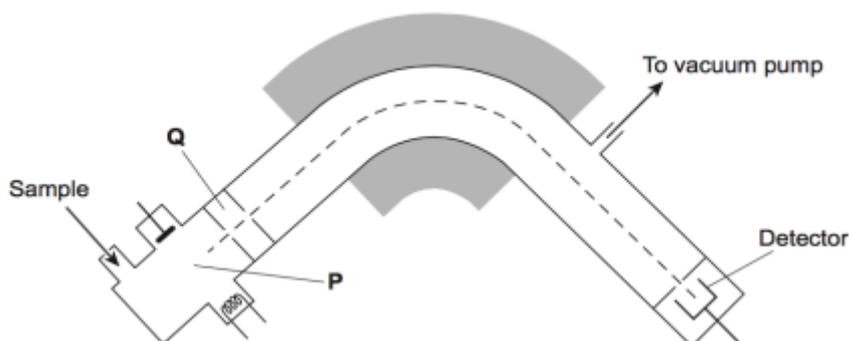
- (a) State the meaning of the term *mass number* of an isotope. (1 mark)

the number of protons + neutrons in the nucleus

- (b) Give the symbol of the element that has an isotope with a mass number of 68 and has 38 neutrons in its nucleus. (1 mark)



The following shows a simplified diagram of a mass spectrometer.



- (c) State what happens to the sample in the parts labelled **P** and **Q**.

P ionisation (by beam of electrons)

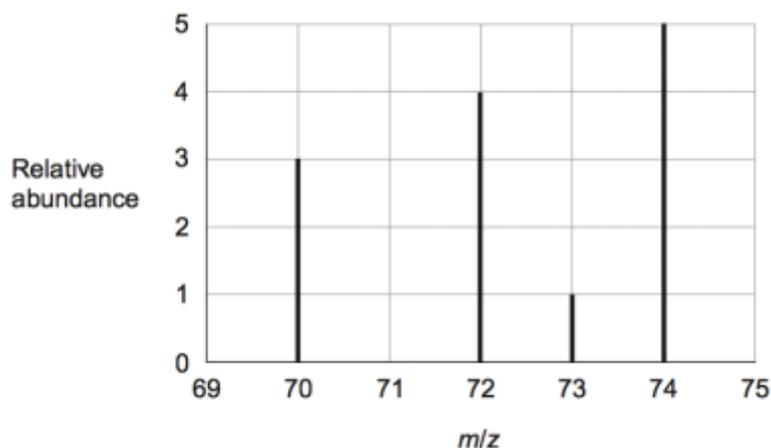
Q acceleration (2 marks)

In a mass spectrometer, the isotopes of an element are separated. Two measurements for each isotope are recorded on the mass spectrum.

- (d) State the **two** measurements that are recorded for each isotope. (2 marks)

Measurement 1 **relative abundance** Measurement 2 **mass/charge ratio**

- (a) The mass spectrum of the isotopes of element **X** is shown in the diagram.



DO NOT WRITE IN THIS AREA

- (f) Use data from the diagram to calculate the relative atomic mass and the identity of **X**.

$$\frac{(70 \times 3) + (72 \times 4) + (73 \times 1) + (74 \times 5)}{13}$$

$$= 72.4$$

Name of element X: **Germanium** (4 mark)

- (g) Give the formulae of the ion responsible for the peak at 72 (1 mark)



- (h) Identify which **one** of the isotopes of **X** is deflected the most in the magnetic field of a mass spectrometer. Give a reason for your answer.

Isotope **⁷⁰Ge⁺** (or **Germanium-70**)

Reason **lowest mass/charge ratio** (2 marks)

- (i) **X** and **Se** are different elements. Explain why the chemical properties of **X** and **Se** are different.

They have a different number of valence electrons (1 mark)

Question 24 (5 marks)

The four major types of bonds are ionic, metallic, covalent and weak intermolecular forces. List which types of bonds are broken in the following changes:

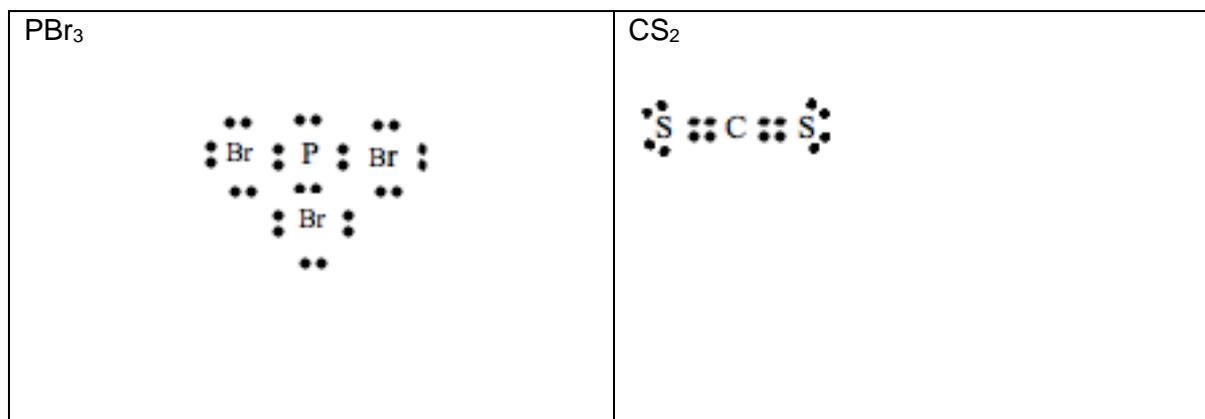
- (a) the melting of sodium nitrate **ionic**
- (b) the burning of petrol (C₈H₁₈) **covalent**
- (c) the boiling of ethanol **weak intermolecular**
- (d) the sublimation of carbon dioxide **weak intermolecular**
- (e) the dissolving of ammonium chloride in water **ionic**

Question 25

(4 marks)

Draw the electron dot diagrams (Lewis structures) of the compounds below.

All valence shell electron pairs should be represented as \cdot or $-$

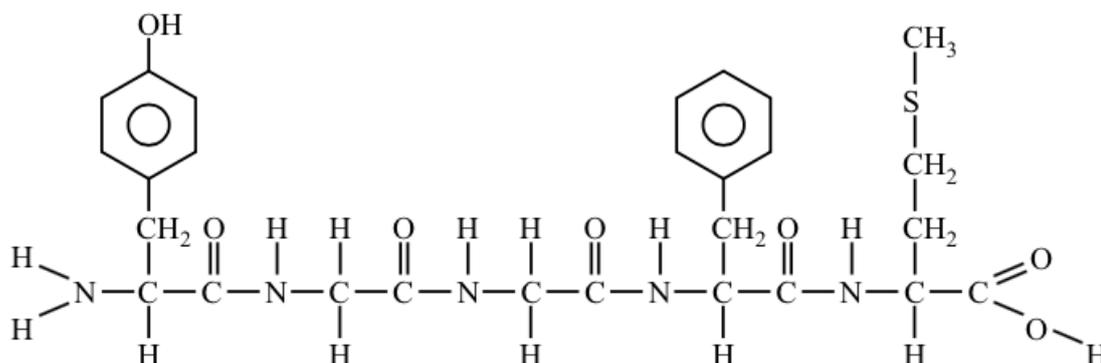


Question 26

(9 marks)

Chromatography is often used for the analysis of the mixture of amino acids that is formed when proteins are broken down. The small protein methionine enkephalin has some painkilling activity. The amino acids that make up this protein include methionine, phenylalanine, tyrosine and glycine.

The structure of the protein methionine enkephalin is given below.



(a) **Circle** a benzene ring in the **above structure** (1 mark)

(b) Given that the molecular formula of methionine enkephalin is C₂₇ N₅ H₃₅ SO₇. Calculate the molar mass of the compound.

(1 mark)

$$(27 \times 12.01) + (5 \times 14.01) + (35 \times 1.008) + 32.07 + (7 \times 16.00)$$

$$= 573.7 \text{ g mol}^{-1}$$

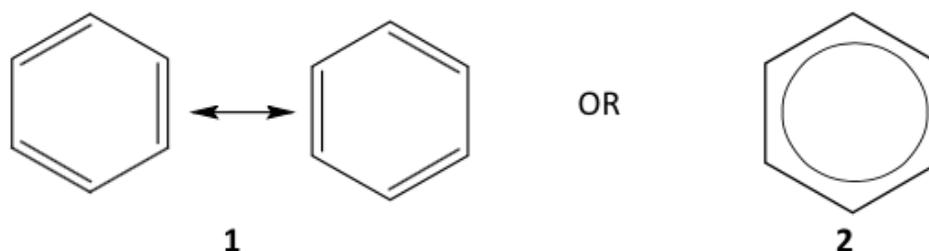
(c) How many molecules of methionine enkephalin are there in 6.50g of the molecule?

$$n(\text{methionine}) = \frac{m}{M} = \frac{6.50}{573.7} = 1.133 \times 10^{-2} \text{ mol}$$

$$N = n \times 6.022 \times 10^{23} = 1.133 \times 10^{-2} \times 6.022 \times 10^{23} = 6.82 \times 10^{21} \text{ molecules}$$

(2 marks)

(d) The structure of benzene is represented by two 6-membered rings with double bonds shown in alternate positions and a double headed arrow between the two 6-membered rings (1) or by a single 6-membered ring with a circle in the centre (2).

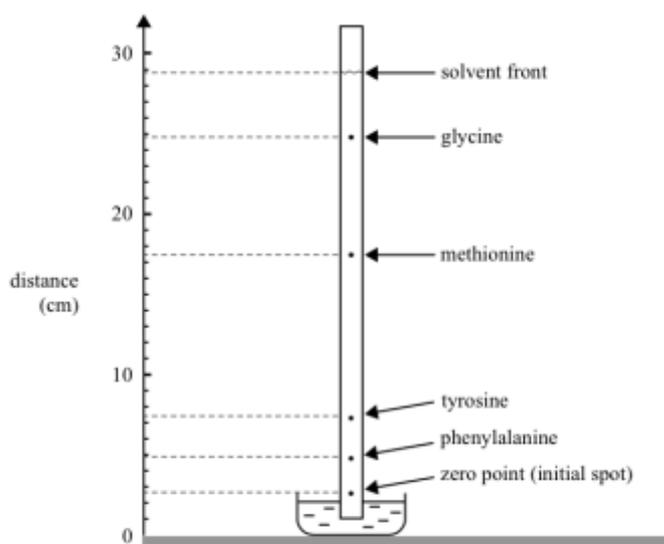


Using your knowledge of the structure and bonding of benzene, explain why aromatic compounds like benzene do not undergo addition reactions, like alkenes but reacts via substitution reactions, similar to alkanes.

Double bonds are required for addition reactions. Due to benzenes structure each carbon forms 3 single covalent bonds leaving its fourth valence electron delocalized within the ring. The bonds between carbons are neither single nor double but somewhere in between.

(2 marks)

An aqueous solution of methionine enkephalin is broken down into its constituent amino acids and the resultant solution of amino acids is subjected to paper chromatography. A strip from such a chromatogram is shown below.



Amino acids are colourless, but the position of an amino acid spot on the strip can be seen by spraying the strip with a solution of ninhydrin, a substance that reacts with amino acids to produce an intense purple colour.

- a. List the amino acid components in order of decreasing solubility in water. (You may use the first letter of the amino acid to identify it).

Most soluble **G M T P** least soluble

(2 marks)

- b. This chromatogram shows a spot of methionine at 17.5 cm on this scale. Calculate the retention factor(R_f) value for methionine.

$$R_f = \frac{17.5-2.7}{29.0-2.7} = 0.56$$

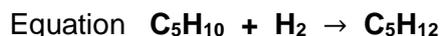
(1 mark)

Question 27

(5 marks)

- (a) Write an equation for the reaction of hydrogen with pent-2-ene in the presence of a suitable catalyst

(2 marks)



- (b) Draw the structural formula or name the following compounds.

(3 marks)

Name	Structural Formula
trans-1-chloropropene	$ \begin{array}{c} \text{Cl} \quad \quad \text{H} \\ \diagdown \quad \diagup \\ \text{C} = \text{C} \\ \diagup \quad \diagdown \\ \text{H} \quad \quad \text{CH}_3 \end{array} $
3,3,5-trimethylheptane	$ \begin{array}{c} \text{CH}_3 \quad \quad \text{CH}_3 \\ \quad \quad \\ \text{CH}_2 - \text{CH} - \text{CH}_2 - \text{C} - \text{CH}_3 \\ \quad \quad \\ \text{CH}_3 \quad \quad \text{CH}_2 \\ \quad \quad \\ \quad \quad \text{CH}_3 \end{array} $
5-ethyl-2,2-dimethyloct-3-ene	$ \begin{array}{c} \text{CH}_3 \\ \\ \text{CH}_3 - \text{C} - \text{CH} = \text{CH} - \text{CH} - \text{CH}_2 - \text{CH}_2 - \text{CH}_3 \\ \quad \quad \\ \text{CH}_3 \quad \quad \text{CH}_2 \\ \quad \quad \\ \quad \quad \text{CH}_3 \end{array} $

Question 28**(2 marks)**

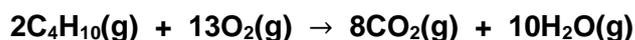
What is the percentage by mass of water in copper sulfate penta-hydrate $\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$?

$$\% \text{H}_2\text{O} = \frac{5 \times 18.01}{249.7} \times 100 = 36.08\% \text{ (36.1\%)}$$

Question 29**(5 marks)**

Butane gas burns readily in oxygen to produce carbon dioxide gas and water vapour.

- (a) Write a balanced equation for this reaction. Include all state symbols.

**(2 marks)**

- (b) 5.50L of air, which is 20% oxygen by volume, is reacted with an excess of butane. What volume of carbon dioxide gas is produced if the gases are cooled to STP conditions?

$$v(\text{O}_2) = 20\% \text{ of } 5.50 = 1.10 \text{ L}$$

(3 marks)

(since = volumes of gases contain = moles at same T and P)

$$v(\text{CO}_2) = \frac{8}{13} \times v(\text{O}_2) = \frac{8}{13} \times 1.10 = 0.677 \text{ L}$$

or/ $v(\text{O}_2) = 20\% \text{ of } 5.50 = 1.10 \text{ L}$

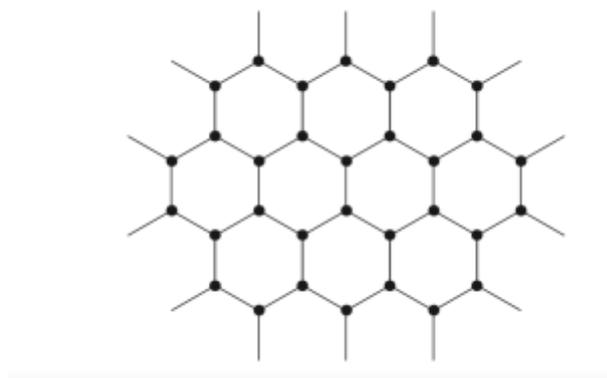
$$n(\text{O}_2) = \frac{1.10}{22.71} = 4.84 \times 10^{-2}$$

$$n(\text{CO}_2) = \frac{8}{13} \times 4.84 \times 10^{-2} = 0.2989$$

$$v(\text{CO}_2) = n \times 22.71 = 0.2989 \times 22.71 = 0.677 \text{ L}$$

Question 30**(8 marks)**

Graphene is a new material made from carbon atoms. It is the thinnest and strongest material known and is a single layer of hexagonal planes of carbon atoms. Graphene has an extremely high melting point and is an excellent conductor of electricity. Part of the structure of graphene is illustrated in the diagram.



- (a) Deduce the type of crystal structure shown by graphene. **covalent network** (1 mark)
- (b) Suggest why graphene is an excellent conductor of electricity.

only 3 of carbons 4 valence electrons are involved in covalent bonds within the layers, the fourth electron is delocalised between layers and are available to carry electric charge.

(2 marks)

- (c) Explain, in terms of its structure and bonding, why graphene has a high melting point. (2 marks)

strong covalent bonds between carbon atoms extend throughout the network and must be overcome. A large amount of energy is required to disrupt these bonds explaining the high melting point.

- (d) Titanium is also a strong material that has a high melting point. It has a structure similar to that of magnesium.

State the type of crystal structure shown by titanium. **metallic** (1 mark)

Titanium can be hammered into objects with different shapes that have similar strengths.

Suggest why titanium can be hammered into different shapes. (2 marks)

metallic crystals are a 3D arrangement of cations surrounded by a sea of delocalised valence electrons. As these electrons can move, when force is applied the layers of cations can slide past each other without repulsion.

Question 31 (5 marks)

F⁻, Ne, Na⁺ and Mg²⁺ all have the same ground state electron configuration.

- (a) What is this electron configuration? **2,8** (1 mark)
- (b) Will the energy required to remove an electron from the different species in (a) be the same or different? Circle your answer.

Same
Different
(1 mark)

- (c) Explain your answer to part (b). (3 marks)

	F ⁻	Ne	Na ⁺	Mg ²⁺
nuclear charge	9+	10+	11+	12+

all species have same electron configuration and therefore same shielding of nuclear charge by inner full electron shell. The increase in nuclear charge means that after shielding the fluoride ion has the lowest attractive force acting on its valence shell and the magnesium ion the highest. The stronger the attraction the nucleus has for its valence electrons the higher the energy required (ionisation energy) to remove an electron.

Section Three: Extended answer**30% (50 Marks)****Question 32****(15 marks)**

Crude oil is a mixture of a very large number of hydrocarbons that can be used as petrol, kerosene, diesel, lubricating oils and waxes.

- (a) Name the process used to separate the hydrocarbons and describe the physical property that allows this separation technique to work successfully.

process - Fractional distillation physical property – different boiling points

(2 marks)

The group of alkanes, or fraction, that has between five and twelve carbon atoms ($C_5 - C_{12}$), is the fraction used in petrol.

The table below gives some of the boiling point values for the **straight chain** alkanes in the $C_5 - C_{12}$ fraction.

Number of carbon atoms	5	6	8	9	10	11
Approximate boiling points	36	70	125	150	174	200

- (b) On the grid provided below, plot a graph of the number carbon atoms against their boiling points.

(4 marks)

- (c) Using the graph, determine the boiling point of the straight chain alkane that has 7 carbon atoms.

Boiling point C_7 **94°C read from graph**

(1 mark)

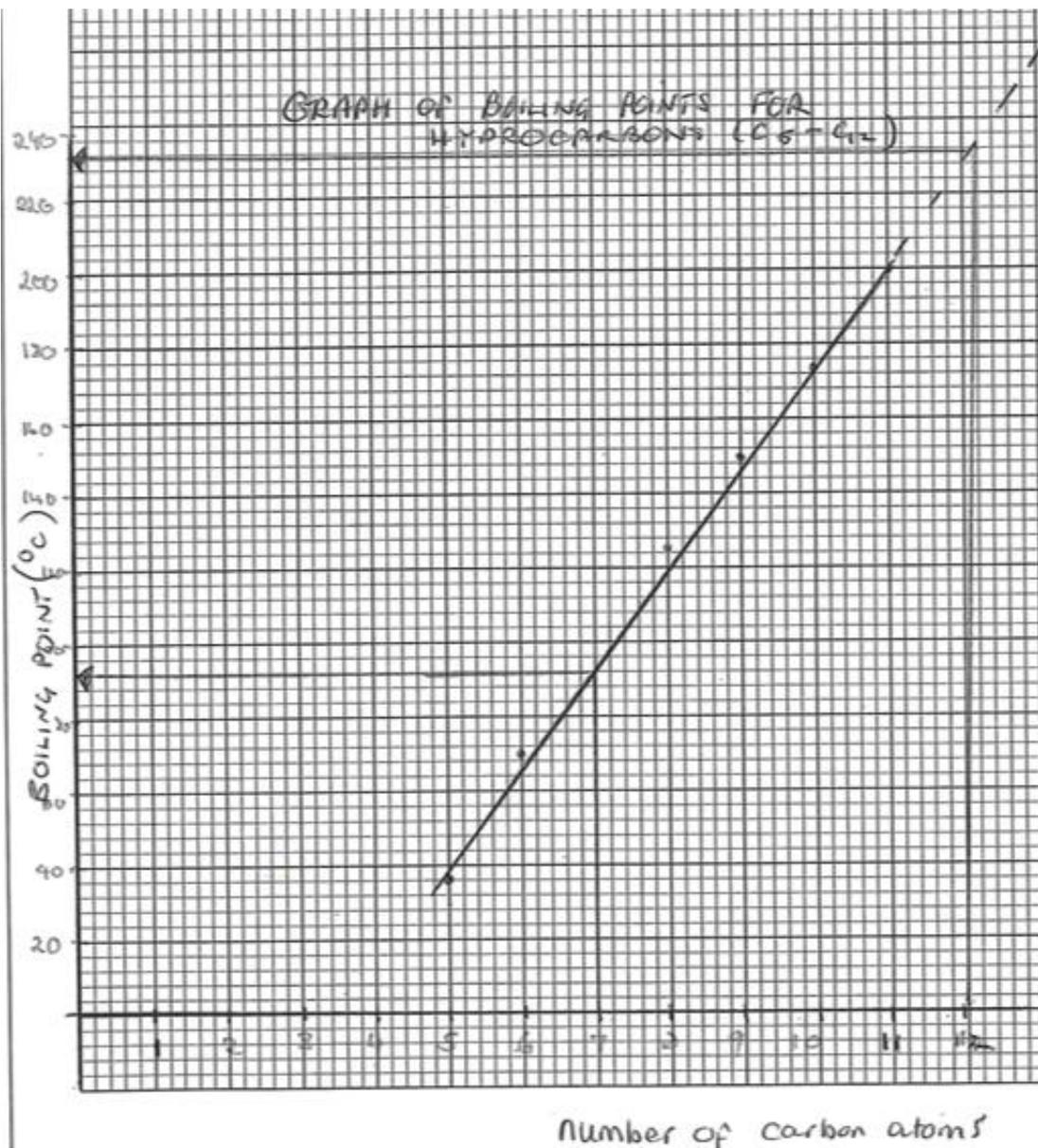
- (d) Extrapolate the graph and predict the boiling point of the straight chain alkane that has 12 carbon atoms.

Boiling point C_{12} **228 °C read from graph**

(1 mark)

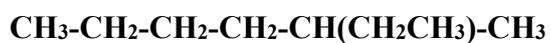
Straight chain alkanes with 5-12 carbon atoms are not very suitable for use in automobile engines because they ignite too readily and have a low octane number. This is dangerous as it means that the mixture may explode in the automobile engine.

Branched chain alkanes however ignite at higher temperatures compared to the straight chain alkanes with similar number of carbons. A reforming process involving high temperature and pressure is used to convert the low octane alkanes into fractions that do not burn as readily. In order to meet the demand for these fractions with five to twelve carbons, the heavier fractions are subjected to "cracking" that will break the larger alkanes into smaller branched alkanes.



- (f) Dodecane (C₁₂H₂₆) is a liquid hydrocarbon that undergoes thermal cracking to produce but-2-ene and another branched chain alkane, that is a structural isomer of octane.

Draw the structural formulae for the two products.



or any branched isomer of octane C₈H₁₈

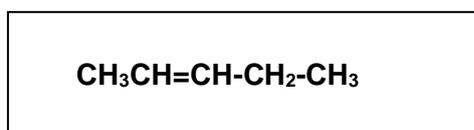
(2 marks)

- (g) A student has test tubes containing two different colourless, organic liquids, both with the molecular formula C_5H_{10} . She decided to carry out a chemical test to distinguish the two and added bromine water to both, mixing the reagents by shaking, being careful to omit any UV light. **The liquids were labelled A and B.** She tabulated her observations below:

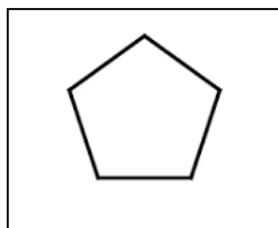
Organic liquid	Observations
Liquid A	Immediately decolourised the solution from orange to colourless
Liquid B	Solution remained orange

Further analysis revealed that one of the organic compounds could form geometric isomers. Based on the observations and this information, suggest a possible structure for liquid A and liquid B.

(2 marks)



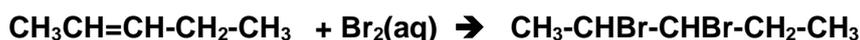
Structure A



Structure B

- (h) Write a balanced equation (using structural formula) for the reaction that gave a positive change to the colour of the bromine water above. **Name** the organic product formed.

(2marks)



Name of organic product: **2,3-dibromopentane**

(1 mark)

Question 33

(9 marks)

Two students were provided with a powdered mixture of calcium phosphate and sodium carbonate and they were carrying out a gravimetric analysis to determine the percentage by mass of calcium phosphate in the mixture.

The students added distilled water to 6.53g mixture of the two compounds until the addition of water results in no further dissolving. They filter the mixture and wash and dry the residue, and measure the mass of the residue. The results are as follows:

Mass of mixture	6.53g
Mass of filter paper	1.56g
Mass of filter paper + residue	5.32g

- (a) Is the original mixture, homogenous or heterogeneous? **heterogeneous**

(1 mark)

- (b) Identify the residue, giving its formula. **Ca₃(PO₄)₂** (1 mark)
- (c) What kind of mixture is the filtrate? **homogenous mixture (solution)** (1 mark)
- (d) Calculate the percentage by mass of calcium phosphate in the original mixture.

Mass of mixture = 6.53

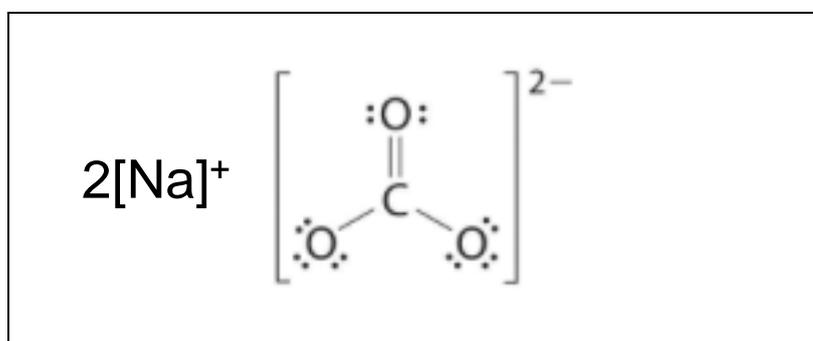
Mass of residue = 5.32 - 1.56 = 3.76g

$$\% \text{ by mass Ca}_3(\text{PO}_4)_2 = \frac{3.76}{6.53} \times 100 = 57.6\% \quad (2 \text{ marks})$$

- (e) Sodium carbonate is not able to conduct electricity in the solid state. Explain. (2 marks)

Sodium carbonate is ionic and has ions in fixed positions in the solid state and so no ions are free to move and carry charge.

- (f) Draw an electron dot diagram (Lewis structure) of sodium carbonate. (2 marks)



Question 34

(17 marks)

The table below shows physical data for period 3 elements.

Element	Na	Mg	Al	Si	S	P	Cl	Ar
Melting point °C	98	650	659	1410	119	44	-101	-150

Use the data above to answer the following questions.

- (a) Explain in terms of bonding and structure why the melting point increases across the elements Na, Mg and Al.

All the elements are metallic with strong metallic bonds between the cations and delocalised electrons. Across period 3 the size of the cation of elements Na, Mg and Al is decreasing as the nuclear charge increases and the electron shells are pulled in more tightly. As the shielding by the inner electrons is constant, so the effective charge of the cation increases. (The charge density of the cation is increasing) There are more delocalised electrons in metallic aluminium (3), than magnesium (2) and sodium (1) and so the force of attraction between the cation and the delocalised electrons is stronger. More energy is required to overcome the metallic bond and the melting point is higher.

(3 marks)

(b) Write the electron arrangement for Mg⁺ ion in its ground state. **2,8,1** (1 mark)

(c) Explain what the term **first ionisation** energy means. (1 mark)

The first ionisation energy is the energy required to remove the most loosely bound electron from 1 mole of the atom in its gaseous state

(d) Write an equation to represent the 2nd ionisation energy of magnesium. (2 marks)



(e) Explain why the second ionisation energy of magnesium is lower than that of sodium

Na 2,8,1 Mg 2,8,2

To remove the second electron from sodium requires more energy as it is being removed from an electron shell closer to the nucleus and less shielded by inner electrons. The force of attraction between this electron and the nucleus will be greater and more energy is needed to remove it.

In magnesium, the second electron is being removed from the valence shell, further from the nucleus and more shielded. Less energy is required to remove this electron.

(3 marks)

(f) Using your understanding of electron arrangement, complete the table and suggest a possible value for the third ionization energy of magnesium

missing value approx. 7500 (1 mark)

	First	Second	Third	Fourth	Fifth
Ionisation energies of magnesium / kJ mol ⁻¹	736	1450		10 500	13 629

(f) State and explain the trends in electronegativity across periods and down group.

Trend down a group: **electronegativity decreases**

Electronegativity is the electron attracting power of an atom. This decreases down a group because the electron is entering a shell further from the nucleus, that is more shielded by inner electrons. As the net nuclear charge (after shielding) is constant down the groups, the force of attraction on the incoming electron is weaker.

Trend across a period: **electronegativity increases**

The electron is entering a shell that is on average closer to the nucleus, with the same shielding but a stronger net nuclear charge, so there is a stronger force of attraction on the incoming electron.

- (g) Explain how the differences in electronegativity between reacting elements determine whether substances formed are ionic or covalent.

If the elements have very different electronegativities (one high, the other low) the resulting compound will be ionic. The most electronegative element gaining complete control of the incoming electron(s) forming the negative ion.

If the elements have similar high electronegativities it results in a covalent substance.

(electrons are shared as neither element has a high enough electronegativity to gain complete control of electron(s).)

(6 marks)

Question 35

(9 marks)

Ammonium nitrate is an important nitrogen rich fertilizer necessary for the growth and well being of plants. Nitrogen helps a plant use carbohydrates to gain energy. It also controls the plant's form and internal function in order to make protein. A commercially available nitrogen rich fertiliser, "Crop-King" has 35.0% ammonium nitrate by mass.

- (a) A 115m² garden bed of roses requires 1.20kg of nitrogen weekly to help maintain their growth. What mass of the "Crop-King" fertiliser is required to be administered to the area weekly if it contains 35.0% ammonium nitrate by mass?

(4 marks)

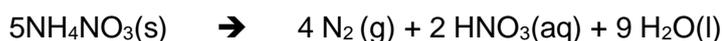
$$n(\text{N}) = 1200/14.01 = 85.653 \text{ mols}$$

$$n(\text{NH}_4\text{NO}_3) = \frac{1}{2} n(\text{N}) = 42.8265 \text{ mols}$$

$$m(\text{NH}_4\text{NO}_3) = nM = 42.8265 \times 80.052 = 3428.34\text{g}$$

$$\text{If only 35\% m (crop king) } = 3428.34\text{g} \times 100/35 = 9.80\text{kg}$$

- (b) Ammonium nitrate is also used as an explosive for detonating buildings. Thermal decomposition of ammonium nitrate in the presence of a catalyst takes place according to the following reaction:



When ammonium nitrate is heated strongly with a catalyst. 60.0L of nitrogen gas is produced when cooled to STP conditions. What mass of ammonium nitrate is required to produce this volume of nitrogen?

$$n(\text{N}_2) = 20/22.71 = 2.64200 \text{ mols}$$

$$n(\text{NH}_4\text{NO}_3) = 5/4 n(\text{N}_2) = 3.302509 \text{ mols}$$

$$m(\text{NH}_4\text{NO}_3) = nM = 264\text{g (3sf)}$$

(3 marks)

- (c) When the temperature is increased on this system, at constant volume, explain what effect this will have on the pressure of the nitrogen gas inside the reaction vessel.

As temperature is increased, the average kinetic energy of the gas particles increases. Particles will collide with greater frequency and force in fixed volume. Pressure will increase.

(2 marks)

END OF QUESTIONS