**Insert School Logo**

**Semester One**

**Examination 2023**

**Question/Answer booklet**

**CHEMISTRY**

**UNIT 1**

Name: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Teacher: \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

***TIME ALLOWED FOR THIS PAPER***

Reading time before commencing work: Ten minutes

Working time for the paper: Three hours

***MATERIALS REQUIRED/RECOMMENDED FOR THIS PAPER***

**To be provided by the supervisor:**

This Question/Answer Booklet

Multiple-choice Answer Sheet

Chemistry Data Book

**To be provided by the candidate:**

Standard items: pens, pencils, eraser or correction fluid, ruler, highlighter.

Special items: calculators satisfying the conditions set by the SCSA for this subject.

***IMPORTANT NOTE TO CANDIDATES***

No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

**Structure of this paper**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Section | Number of questions available | Number of questions to be answered | Suggested working time  (minutes) | Marks available | Percentage of exam |
| Section One:  Multiple-choice | 25 | 25 | 50 | 25 | 25 |
| Section Two:  Short answer | 9 | 9 | 60 | 75 | 35 |
| Section Three:  Extended answer | 5 | 5 | 70 | 90 | 40 |
|  |  |  |  | **Total** | 100 |
| Final percentage | | x 25 + x 35 + x 40 = | | | % |

**Instructions to candidates**

1. Answer the questions according to the following instructions.

Section One: Answer all questions on the separate Multiple-choice Answer Sheet provided. For each question shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Sections Two and Three: Write your answers in this Question/Answer Booklet.

2. When calculating numerical answers, show your working or reasoning clearly. Express numerical answers to the appropriate number of significant figures and include appropriate units where applicable.

3. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

4. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

* + Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
  + Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

5. The Chemistry Data Book is **not** handed in with your Question/Answer Booklet.

**Section One: Multiple-choice 25% (25 marks)**

This section has **25** questions. Answer **all** questions on the separate Multiple-choice Answer Sheet provided. For each question, shade the box to indicate your answer. Use only a blue or black pen to shade the boxes. If you make a mistake, place a cross through that square then shade your new answer. Do not erase or use correction fluid/tape. Marks will not be deducted for incorrect answers. No marks will be given if more than one answer is completed for any question.

Suggested working time: 50 minutes.

**Questions 1, 2 and 3 refer to the information in the following table.**

Consider the information provided about the **neutral** atoms in the partially completed table below.

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Species | Symbol | Number of protons | Number of neutrons | Electron configuration | Mass number |
| W |  | 7 |  |  | 15 |
| X |  | 8 | 8 |  |  |
| Y |  | 6 | 7 |  |  |
| Z |  |  |  | 2, 6 |  |

1. What is the correct symbol for species Y?

2. Identify the ground state electron configuration for species W.

1. 2, 5
2. 2, 7
3. 2, 4, 1
4. 2, 8, 5

3. Which of these species are isotopes of one another?

1. W and X
2. X and Y
3. W and Y
4. X and Z

4. Which of the following statements regarding pure substances is **not** correct?

(a) All elements are pure substances.

(b) All compounds are pure substances.

(c) All pure substances have a chemical formula.

(d) All pure substances are unable to be separated.

5. Which of the following compounds contains **both** ionic and covalent bonding?

1. Ethene
2. Cobalt oxide
3. Lithium sulfate
4. Manganese(II) chloride

6. A sample of chlorine gas contained 6.022 x 1023 atoms of chlorine. The number of moles of chlorine gas present in the sample was

(a) 0.5 moles.

(b) 1.0 moles.

(c) 2.0 moles.

(d) 6.022 x 1023 moles.

7. An atom with a valency of 2- would be **least** likely to form

1. single covalent bonds.
2. double covalent bonds.
3. triple covalent bonds.
4. ionic bonds.

8. The scientist J.J. Thomson contributed to our understanding of atomic structure with his discovery of the

1. proton.
2. neutron.
3. electron.
4. nucleus.

9. Mass spectrometry involves the ionisation of substances, which is caused by the removal of an electron from each species. This results in the formation of

1. cations.
2. anions.
3. a mixture of cations and anions.
4. metal cations and non-metal anions.

**Questions 10 and 11 refer to the information below.**

Consider the information provided in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
| **Substance** | **Density** | **Solubility in water** | **Boiling point** |
| potassium nitrate,  KNO3(s) | 2.11 g / cm3 | soluble | 400 °C |
| lead(II) iodide,  PbI2(s) | 6.16 g / cm3 | insoluble | 954 °C |
| ethanol,  C2H5OH(l) | 0.789 g / mL | soluble | 78.4 °C |
| octane,  C8H­18(l) | 0.703 g / mL | insoluble | 126 °C |

10. Which of the following mixtures would be easiest to separate using a filter funnel lined with filter paper?

1. Potassium nitrate and water.
2. Lead(II) iodide and water.
3. Ethanol and water.
4. Octane and water.

11. Which of the following mixtures would be easiest to separate using a separating funnel?

1. Potassium nitrate and water.
2. Lead(II) iodide and water.
3. Ethanol and water.
4. Octane and water.

12. How many electrons are in the third energy level when an atom of potassium is in the ground state?

1. 1
2. 8
3. 18
4. 19

13. Consider the thermochemical equation below.

2 H2(g) + O2(g) → 2 H2O(g) + 572 kJ

This equation shows that for

1. 1 mole of H2(g) consumed, 572 kJ of energy is released.
2. 1 mole of O2(g) consumed, 572 kJ of energy is released.
3. 1 mole of H2(g) consumed, 572 kJ of energy is absorbed.
4. 1 mole of O2(g) consumed, 572 kJ of energy is absorbed.

14. A flame test was performed on an unknown powder, and the following line emission spectrum was produced.

Which of the metals below were present in the powdered sample?

Li

Na

Zn

Cu

1. Li and Zn.
2. Li and Cu.
3. Na and Zn.
4. Na and Cu.

15. Which of the following is the **best** explanation for why krypton is an inert gas?

(a) It is a Noble gas.

(b) It is in Group 18 of the periodic table.

(c) Its valence electron shell is full.

(d) It contains 8 electrons in its valence shell.

16. Which of the following organic compounds has a different molecular formula to the others?

1. 2,3,4-trimethylhexane
2. 3-ethylhexane
3. 3,3-diethylpentane

(d) 2,5-dimethylheptane

**Questions 17 and 18 refer to the following investigation.**

A group of chemistry students investigated the decomposition of hydrogen peroxide. The chemical reaction for this process is given below.

MnO2(s)

2 H2O2(l) 2 H2O(l) + O2(g)

A sample of hydrogen peroxide was poured into a beaker containing some pellets of manganese(IV) oxide catalyst. The initial mass of the beaker and contents was quickly measured and recorded.

H2O2(l)

MnO2(s)

XXX.XX g

As the decomposition began, bubbles of colourless, odourless gas were observed to form. The beaker was then left until no more effervescence could be seen, and the final mass of the beaker and its contents was recorded.

This procedure was repeated five times. The students found that, on average, the mass of the beaker decreased by 5.73 g during the decomposition.

17. Based on your understanding of chemical processes, which of the following conclusions is the **most likely** explanation for this result?

The decrease in mass of the conical flask

1. shows that the Law of Conservation of Mass is not upheld.
2. is equal to the enthalpy change of the reaction.
3. is due to an increase in the temperature of the surroundings.
4. is equal to the mass of oxygen gas produced.

During the evaluation of the investigation, one student discovered that the balance had not been calibrated properly and was producing readings that were consistently 0.34 g higher than the actual value. Another student noted that fluctuations in atmospheric pressure during the investigation would also have contributed to discrepancies in the mass readings taken.

18. Classify each of these errors as random or systematic.

**Incorrect calibration Pressure fluctuations**

1. systematic systematic
2. systematic random
3. random random
4. random systematic

19. The molecule below is called cinnamic acid and is found in cinnamon oil.



The molecular formula of cinnamic acid is

1. C8H7O2.
2. C9H3O2.
3. C9H7O2.
4. C9H8O2.

20. Consider the information provided in the incomplete graph below.

Which periodic trend is being illustrated by this graph?

1. Atomic radius.
2. Valency.
3. First ionisation energy.
4. Electronegativity.

21. Consider elements X and Y, which have the following electron configurations;

X 2, 8, 5

Y 2, 7

When these elements form chemical bonds, their valence electrons are likely to be

1. delocalised.
2. transferred.
3. shared.
4. lost.

22. Which of the following is the **best** explanation for why metals are ductile?

Metals have

1. delocalised electrons.
2. low ionisation energies.
3. non-directional bonding.
4. weak intermolecular forces.

23. Many types of bioluminescent fungi contain the compound 3-hydroxyhispidin. This compound reacts, in the presence of oxygen, to produce light which causes the fungi to glow.

For this reaction, it can be concluded that

1. the reactants have a higher enthalpy than the products.
2. the system has taken in energy from the surroundings.
3. the sign of the enthalpy change is positive.
4. the quantity of energy required to break the reactant bonds is large.

24. Consider the balanced chemical equation below.

4 NH3(g) + 5 O2(g) → 4 NO(g) + 6 H2O(g)

Which of the following stoichiometric relationships is correct?

1. n(NO) = x n(O2)
2. n(NO) = x n(O2)
3. n(NO) = x n(NH3)
4. n(NO) = x n(NH3)

25. Consider the organic molecule below.



Which reactants could have been mixed together to produce this compound?



(a)

(b)

(c)

(d)

**End of Section One**

**Section Two: Short answer 35% (75 marks)**

This section has 9 questions. Answer **all** questions. Write your answers in the spaces provided.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 60 minutes.

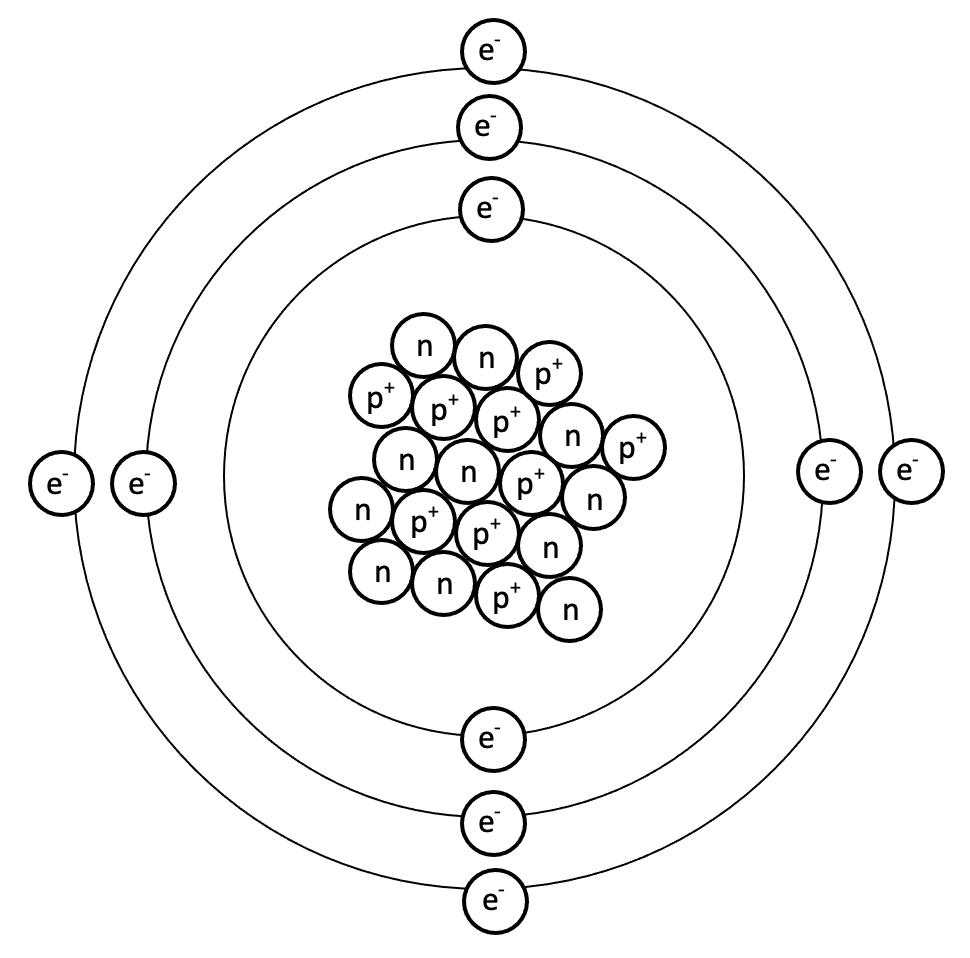
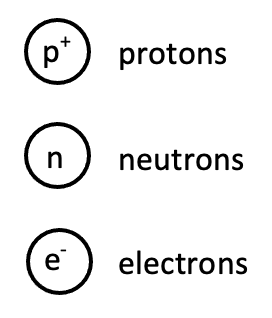
**Question 26 (6 marks)**

Complete the following table, by writing either the name or the formula of the compound.

|  |  |
| --- | --- |
| **Name** | **Formula** |
| aluminium fluoride |  |
|  | NH3 |
| dibromine monoxide |  |
| potassium ethanoate |  |
|  | Fe2(CO3)3 |
| phosphoric acid |  |

**Question 27 (7 marks)**

A student was asked to draw a diagram showing the subatomic particle arrangement of an atom of neon-20. They subsequently produced the sketch below.



(a) Identify three (3) errors in this diagram, indicating how each could be corrected. (6 marks)

|  |  |
| --- | --- |
| 1 |  |
| 2 |  |
| 3 |  |

(b) Correctly identify the species drawn by the student in the original sketch. (1 mark)

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**Question 28 (7 marks)**

Mass spectrometry was performed on a sample of chromium and the following data was obtained.

(a) How many isotopes of chromium are present in this sample? (1 mark)

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(b) Compare these isotopes of chromium, in terms of their subatomic particles. (3 marks)

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(c) Define the ‘relative atomic mass’ of an element. (1 mark)

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(d) Calculate the relative atomic mass of this chromium sample. (2 marks)

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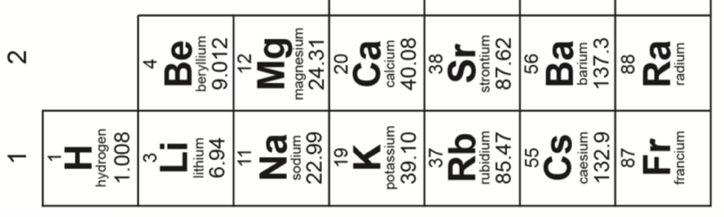
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**Question 29 (12 marks)**

Sodium (Na) and rubidium (Rb) are both located in group 1 of the periodic table.



(a) State the name given to the group 1 elements. (1 mark)

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(b) Why are sodium and rubidium placed in group 1? (1 mark)

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(c) Identify which of these two elements is more reactive, and explain your answer in terms of first ionisation energy. (4 marks)

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Chlorine (Cl) and iodine (I) are both located in group 17 of the periodic table.

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(d) State the name given to the group 17 elements. (1 mark)

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(e) Why do chlorine and iodine have the same 1– valency? (1 mark)

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(f) Identify which of these two elements is more reactive, and explain your answer in terms of electronegativity. (4 marks)

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**Question 30 (8 marks)**

Researchers have recently developed nano-sensors made from collections of gold nanorods. These nano-sensors have shown the ability to detect extremely small amounts of substances.

Depending on the size of the gold nanorods, they appear red or blue-green in colour. Their electrical conductivity and melting point will also vary, depending upon size. Gold nanorods also show catalytic properties, for example in the oxidation of carbon monoxide gas.

The new nano-sensors are produced when gold nanorods cluster together to form a 3D spherical ‘supraparticle’.

gold nanorod

‘supraparticle’ of gold nanorods

The individual gold nanorods used are approximately 64 nm in length and 19 nm in diameter, and these then form ‘supraparticles’ with a diameter of between 600-1000 nm.

(a) Justify why individual gold nanorods are classified as nanoparticles but gold ‘supraparticles’ are not. (2 marks)

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(b) Compare gold nanorods and bulk gold, and identify one (1) similarity and one (1) difference in their properties. (2 marks)

|  |  |
| --- | --- |
| Similarity |  |
| Difference |  |

Aflatoxin B1 (C17H12O6) is a carcinogen produced by fungus. Agricultural products and food are continuously monitored for the presence of aflatoxin B1 as it is a common contaminant.

Gold nanorods have been shown to detect aflatoxin B1 at concentrations as low as 0.16 ng mL-1 (nanograms per millilitre).

(c) Calculate the number of aflatoxin B1 molecules present in a 1 mL sample of solution where the concentration of aflatoxin B1 was 0.16 ng mL-1. (4 marks)

Note: 1 ng = 1.0 x 10-9 g

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**Question 31 (11 marks)**

Crude oil consists of a mixture of organic compounds, primarily alkanes. These compounds are of various lengths and must be separated before use.

(a) What is an ‘alkane’? (1 mark)

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(b) Name the process by which crude oil is separated into its various organic components. (1 mark)

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(c) Identify which physical property of the organic components allows this method of separation to be used. (1 mark)

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(d) Complete the table below, by either stating the IUPAC name or drawing a structural diagram of the corresponding organic compound. (8 marks)

|  |  |
| --- | --- |
| **Structural diagram** | **IUPAC Name** |
|  |  |
|  |  |
|  | 3-chloropropene |
|  | 1-iodo-2-methylbutane |

**Question 32 (8 marks)**

A chemist completely combusted a 250 g sample of fuel in excess oxygen. This produced 784 g of carbon dioxide gas. The only fuels the chemist had available for this reaction were butane and pentene.

Prove that the fuel used by the chemist was pentene and not butane. Support your answer with appropriate chemical equations and show all calculations.

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**Question 33 (8 marks)**

Consider the diagram below which shows the heating curve for ethanol (C2H5OH).

**C**

**E**

**D**

**B**

**A**

Section B of the curve represents the ‘latent heat of fusion’. This is defined as the quantity of heat required to convert a given amount of a solid substance into a liquid.

Section D of the curve represents the ‘latent heat of vaporisation’. This is defined as the quantity of heat required to convert a given amount of a liquid substance into a vapour.

(a) Classify the processes of fusion and vaporisation as either endothermic or exothermic. (2 marks)

|  |  |
| --- | --- |
| Fusion |  |
| Vaporisation |  |

(b) Identify the temperature at which ethanol freezes and condenses. (2 marks)

|  |  |
| --- | --- |
| Freezing point |  |
| Condensation point |  |

(c) Explain why the length of section D is always greater than the length of section B on a heating curve. (2 marks)

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The latent heat of vaporisation of ethanol is 42.3 kJ mol-1.

(d) Calculate the quantity of heat energy required to completely vaporise 132 g of liquid ethanol. (2 marks)

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**Question 34 (8 marks)**

Consider the elements magnesium (Mg) and sulfur (S).

(a) Why are these elements both located in period 3 of the periodic table? (1 mark)

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(b) Describe, in terms of electron behaviour, how ionic bonds form between the elements magnesium and sulfur. (4 marks)

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(c) Explain why the resultant compound, magnesium sulfide, is brittle. (3 marks)

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**End of Section Two**

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**Section Three: Extended answer 40% (90 marks)**

This section contains **five (5)** questions. You must answer **all** questions. Write your answers in the spaces provided below.

Where questions require an explanation and/or description, marks are awarded for the relevant chemical content and also for coherence and clarity of expression. Lists or dot points are unlikely to gain full marks.

Final answers to calculations should be expressed to the appropriate number of significant figures.

Supplementary pages for planning/continuing your answers to questions are provided at the end of this Question/Answer booklet. If you use these pages to continue an answer, indicate at the original answer where the answer is continued, i.e. give the page number.

Suggested working time: 70 minutes.

**Question 35 (17 marks)**

Trinitrotoluene (C7H5N3O6) is an explosive material better known as TNT. TNT was first produced in 1863, but for decades the explosive qualities of TNT were not realised, due to its relative stability.

TNT is produced by the successive nitration of toluene, which can be summarised by the chemical equation below.



(a) Identify the systematic IUPAC name for toluene. (1 mark)

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(b) Is TNT produced by a substitution or addition reaction? Justify your answer. (2 marks)

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A solution containing 385 kg of nitric acid was poured into a tank of liquid toluene. Concentrated sulfuric acid was also present in the reaction mixture.

(c) Calculate the maximum mass of TNT that would be produced. State your answer to the appropriate number of significant figures. (6 marks)

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Solid TNT can be detonated by a pressure wave, causing it to explode. In addition to heat, this reaction produces the gases nitrogen, hydrogen and carbon monoxide, as well as solid carbon in the form of soot.

(d) Write a balanced chemical equation for the detonation of TNT. Include state symbols in your answer. (3 marks)

|  |
| --- |
|  |

(e) Identify whether this reaction is endothermic or exothermic, and explain how this relates to the processes of bond breaking and making occurring. (3 marks)

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(f) Explain how this chemical reaction can produce heat, while still conforming to the Law of Conservation of Energy. (2 marks)

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**Question 36 (15 marks)**

Atomic absorption spectroscopy (AAS) is often used in the forensic analysis of gunshot residue. ‘Gunshot residue’ refers to the cloud of gas and particles released when a weapon is fired. Some of the inorganic substances commonly found in gunshot residue are lead (Pb), antimony (Sb) and barium (Ba).

Analysis by AAS can determine the concentration of these metals in a gunshot residue sample. This can then be used to provide information about the type of weapon or bullet used, as well as the distance from which the weapon was fired.

During AAS analysis, a hollow cathode lamp produces an emission spectrum corresponding to the element being analysed.

(a) Explain, in terms of electron behaviour, how an emission spectrum is produced by the hollow cathode lamp. (4 marks)

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(b) Explain why the analysis of lead, antimony and barium would each require a different corresponding emission spectrum to be produced by the hollow cathode lamp. (2 marks)

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A forensic scientist collected gunshot residue samples produced from three (3) identical weapons that contained 3 different types of bullets.

They then analysed the gunshot residues using AAS, to determine the concentration of lead, antimony and barium. The data collected by the forensic scientist is provided in the table below.

|  |  |  |  |
| --- | --- | --- | --- |
| **Concentration**  **(parts per million)** | **Bullet A** | **Bullet B** | **Bullet C** |
| Lead, Pb | 3.279 | 3.672 | 41.940 |
| Antimony, Sb | 0.387 | 0.758 | 1.169 |
| Barium, Ba | 1.711 | 0.808 | 3.607 |

(c) Is this primary or secondary data? (1 mark)

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The scientist had also measured and taken into account the ‘background levels’ of lead, antimony and barium in the environment.

(d) Describe how this increases the validity of the data. (1 mark)

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In addition, the forensic scientist had also collected 3 samples of each gunshot residue, and thus the concentrations given in the table above are averages.

(e) Describe how this increases the reliability of the data. (1 mark)

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(f) Suggest a reason that the data collected by forensic scientists needs to have high validity and reliability. (1 mark)

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A gunshot residue sample was collected from a crime scene and analysed by AAS.

The calibration curves for the 3 relevant metals are presented below.

The results of the AAS analysis on the gunshot residue taken from the crime scene are given in the following table.

|  |  |  |  |
| --- | --- | --- | --- |
| **Metal residue** | Lead, Pb | Antimony, Sb | Barium, Ba |
| **Absorbance** | 0.16 | 12 | 2.4 |
| **Concentration**  **(ppm)** |  |  |  |

(g) Complete the table above, by calculating the concentration of lead, antimony and barium present in the gunshot residue. (4 marks)

(h) Which type of bullet (A, B or C) is most likely to have been used in this crime? (1 mark)

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**Question 37 (17 marks)**

Solders are metal alloys which have low melting points and are used to join pieces of metal together. They are applied in molten form, and then allowed to solidify, resulting in pieces of metal being connected. One of the most common solders is composed of lead (Pb) and tin (Sn).

A group of students set out to investigate how the composition of a lead-tin solder would affect its solidification point.

They prepared solders with various composition, by melting different quantities of lead and tin together. Then they allowed the solders to cool and measured the temperature at which solidification of the solder began.

The results they collected are shown in the table below.

|  |  |
| --- | --- |
| **Percent of Sn in the solder (%)** | **Solidification point (°C)** |
| 10 | 310 |
| 40 | 233 |
| 60 | 188 |
| 80 | 222 |
| 90 | 228 |

(a) Plot this data on the grid below. (5 marks)

Chart

Description automatically generated

(b) Use your graph to predict the solidification point of pure lead and pure tin. (2 marks)

|  |  |
| --- | --- |
| Solidification point of lead |  |
| Solidification point of tin |  |

(c) Explain why lead and tin each have a specific solidification point, but a lead-tin solder has a range of different solidification points. (4 marks)

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Solders are often used in electrical applications, such as the manufacture of various electronic components.

(d) Explain, in terms of structure and bonding, why solders can conduct electricity. (2 marks)

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The ‘eutectic point’ of an alloy is the lowest solidification temperature that can be obtained, out of all possible compositions.

For a lead-tin solder, the eutectic point occurs when there is a 3:1 mole ratio of tin to lead present in the alloy.

(e) Calculate the percent composition by mass of this solder at its eutectic point. (4 marks)

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**Question 38 (21 marks)**

Much research has been done on the promising new biofuel 2,5-dimethylfuran (DMF). DMF can be produced directly from the monosaccharide fructose (fruit sugar) or from the polysaccharide cellulose, which can be broken down into glucose and then converted to fructose.

The following flow chart illustrates the pathways used to manufacture DMF.

cellulose

glucose

fructose

DMF

biomass to liquid conversion

**Feedstocks:**

Straw waste from crops such as maize, barley, wheat etc

**Feedstocks:**

Fruits, root vegetables etc

(a) Distinguish between a biofuel and a fossil fuel. (2 marks)

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(b) Identify one (1) advantage of biofuels over fossil fuels. (1 mark)

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The main disadvantage of biofuels such as ethanol, is that they compete with food production, both in terms of land use as well as the raw materials used as feedstocks.

(c) Identify one (1) other disadvantage of biofuels compared to fossil fuels. (1 mark)

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(d) Identify one (1) advantage of using cellulose compared to fructose to produce the biofuel DMF. (1 mark)

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The incomplete table below provides a comparative analysis of DMF against two other common fuels; petrol and ethanol.

|  |  |  |  |
| --- | --- | --- | --- |
|  | **Petrol** | **Ethanol** | **DMF** |
| Origin of fuel | fossil-based | bio-based | bio-based |
| Composition of fuel | mixture of hydrocarbons with between 4 and 12 carbons | CH3CH2OH | C6H8O |
| Air-fuel ratio | 14.7 | ? | 10.7 |
| Density (kg L-1) | 0.7446 | 0.7909 | 0.8897 |
| Heating value  (MJ kg-1) | 42.9 | 29.6 | 32.9 |
| Energy density  (MJ L-1) | ? | 23.4 | 29.3 |
| Molar heat of combustion (kJ mol-1) | **–** | 1360 | ? |

The air-fuel ratio is the mass ratio of air to fuel during combustion. For example, since the air-fuel ratio for petrol is 14.7, this means that for every 1 g of petrol combusted, 14.7 g of air is consumed.

The chemical equation for the combustion of ethanol is given below.

CH3CH2OH(l) + 3 O2(g) → 2 CO2(g) + 3 H2O(g)

(e) Calculate the air-fuel ratio for ethanol. Assume air is composed of 21% O2(g) by mass. (5 marks)

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Whilst petrol has the highest heating value of these fuels, DMF has the highest density, and therefore petrol and DMF are very similar when compared in terms of energy density.

Energy density can be a more useful measure when comparing liquid fuels, as a vehicle generally has a fixed capacity fuel tank.

(f) Calculate the energy density of petrol, and identify which of the three fuels has the highest energy density. (2 marks)

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The molar heat of combustion is another measure by which fuels are compared. This is the amount of energy released upon combustion of 1 mole of fuel.

(g) Why can’t an exact molar heat of combustion be calculated for petrol? (2 marks)

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(h) Calculate the molar heat of combustion (in kJ mol-1) for DMF. (3 marks)

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(i) Use the information gathered, to write a balanced thermochemical equation for the complete combustion of DMF. (4 marks)

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**Question 39 (20 marks)**

A chemistry student was investigating the properties of four (4) large, individual crystals. The identity of the crystals were;

* sugar, C12H22O11(s)
* salt, NaCl(s)
* graphite, C(s)
* diamond, C(s)

Firstly, the student decided to test the electrical conductivity of each crystal.

(a) Sketch a labelled diagram of the equipment set-up, showing how the student could perform this test. (3 marks)

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Only one of the crystals was found to conduct electricity.

(b) Identify this crystal, and explain its electrical conductivity in terms of the structure and bonding present. (3 marks)

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The student took the three remaining crystals and placed them, spaced apart, on a hot plate. The hot plate was turned on. After a few minutes one of the crystals began to melt and the hot plate was turned off again.

(c) Identify this crystal, and explain its low melting point, in terms of the structure and bonding present. (4 marks)

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The student then placed the remaining two crystals (which had not begun to melt) into separate beakers of water, and stirred. One crystal dissolved and one did not.

(d) Identify the crystal that did **not** dissolve, and explain its lack of solubility in terms of the structure and bonding present. (3 marks)

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Upon further investigation of the beaker where the crystal **did** dissolve, the student found that the solution now conducted electricity.

(e) Use chemical notation to represent the solution formed in this beaker. (1 mark)

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(f) Explain why this crystal did not conduct electricity when solid but, upon dissolving, formed a solution that did conduct electricity. (4 marks)

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(g) List two (2) risks the student may have identified, when conducting their risk assessment for this investigation. (2 marks)

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**End of questions**

**Additional working space**

Question number(s): ……………………

**Spare grid**

Question 37 (a)

Chart

Description automatically generated

**Additional working space**

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