**CHEMISTRY**

**UNIT 1**

**2022**

**MARKING GUIDE**

***TIME ALLOWED FOR THIS PAPER***

Reading time before commencing work: Ten minutes

Working time for the paper: 2 hours 30 minutes

***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 | 10 | 10 | 60 | 77 | 35 |
| Section Three  Extended answer | 5 | 5 | 70 | 86 | 40 |
|  |  |  |  | **Total** | 100 |

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

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b □ c □ d ■ |  | 6 | a □ b ■ c □ d □ |  | 11 | a □ b □ c ■ d □ |
| 2 | a □ b □ c ■ d □ |  | 7 | a ■ b □ c □ d □ |  | 12 | a □ b □ c ■ d □ |
| 3 | a □ b □ c □ d ■ |  | 8 | a □ b □ c □ d ■ |  | 13 | a □ b ■ c □ d □ |
| 4 | a ■ b □ c □ d □ |  | 9 | a □ b □ c □ d ■ |  | 14 | a □ b ■ c □ d □ |
| 5 | a □ b ■ c □ d □ |  | 10 | a □ b □ c ■ d □ |  | 15 | a ■ b □ c □ d □ |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 16 | a □ b □ c □ d ■ |  | 21 | a ■ b □ c □ d □ |  |  |  |
| 17 | a □ b □ c ■ d □ |  | 22 | a □ b □ c ■ d □ |  |  |  |
| 18 | a □ b □ c □ d ■ |  | 23 | a ■ b □ c □ d □ |  |  |  |
| 19 | a □ b □ c □ d ■ |  | 24 | a □ b □ c □ d ■ |  |  |  |
| 20 | a □ b ■ c □ d □ |  | 25 | a □ b ■ c □ d □ |  |  |  |

**Section Two: Short answer 35% (77 marks)**

**Question 26 (10 marks)**

(a) Identify the characteristic common to all elements in this row, which results in them being located in period 3 of the modern periodic table. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Valence electrons are in the third shell.  **or**  There are three energy shells with electrons residing in them. | 1 |
| **Total** | **1** |

(b) State and explain the trend in atomic radii, as you move left to right across this row. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Atomic radius decreases (as you move left to right across a period). | 1 |
| This is because the number of protons in the nucleus increases. | 1 |
| Thus increasing the attraction between the valence shell and the nucleus. | 1 |
| **Total** | **3** |

(c) Identify the reason that elements like Cu and Ag are no longer placed in group 1 of the modern periodic table. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| They do not have one valence electron.  **or**  They do not show the same reactivity / chemical properties as group 1 metals. | 1 |
| **Total** | **1** |

(d) Describe how the layout of the periodic table allowed Mendeleev to make predictions such as these. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The periodic table is organised in a recurring way.  **or**  Elements are arranged in the periodic table based on their physical and chemical properties | 1 |
| Comparison with neighbouring elements (left, right, above, below) thus often allows properties of elements to be predicted. | 1 |
| **Total** | **2** |

(e) Identify the element that was later discovered to sit between Ca and Ti. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Scandium | 1 |
| **Total** | **1** |

(f) Explain why the Noble gases are so unreactive. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Noble gases have 8 valence electrons / satisfy the octet rule (with the exception of He which has 2 valence electrons). | 1 |
| This is a very stable electron configuration (resulting in a low reactivity). | 1 |
| **Total** | **2** |

**Question 27 (5 marks)**

Calculate the total number of carbenicillin molecules the patient would have ingested in a 24 hour period.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(carbenicillin in 1 tablet) = 764 / 1000  = 0.764 g | 1 |
| m(carbenicillin each day) = 0.764 x 4  = 3.056 g | 1 |
| M(carbenicillin) = 378.394 g mol-1 | 1 |
| n(carbenicillin) = 3.056 / 378.394  = 0.00807624 mol | 1 |
| N(carbenicillin) = 0.00807624 x (6.022 x 1023)  = 4.86 x 1021 molecules | 1 |
| **Total** | **5** |

**Question 28 (7 marks)**

(a) On the grid below, draw the mass spectrum that would have been produced by this element upon analysis. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  | |  |  |  |  |  |  |  |  |  |   80 81 82 83 84 85 86 87 88  Mass/charge ratio  100 –  90 –  80 –  70 –  60 –  50 –  40 –  30 –  20 –  10 –  Percent abundance (%) | |
| Axes labelled | 1 |
| Appropriate scale on axes | 1 |
| Data points plotted correctly | 1 |
| Column graph | 1 |
| **Total** | **4** |
| Note:   * Accept ‘Relative isotopic/atomic mass’ for x axis label. * Accept ‘Relative percent abundance’ for y axis label, but corresponding data points must then be recalculated correspondingly. | |

(b) Calculate the relative atomic mass and thereby identify this element. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Ar = (3.6 x 80 + 12 x 82 + 12 x 83 + 57 x 84 + 15.4 x 86) / 100 | 1 |
| = 83.804 g mol-1 | 1 |
| Krypton | 1 |
| **Total** | **3** |

**Question 29 (9 marks)**

(a) Use the information provided to complete the table above. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | Number of  protons | Number of neutrons | Electron configuration | Mass number | | V | 18 | **22** | **2, 8, 8** | 40 | | W | **20** | 20 | 2, 8, 8 | **40** | | X | **16** | 18 | **2, 8, 6** | 34 | | Y | **18** | 18 | **2, 8, 8** | 36 | | Z | 16 | **20** | **2, 8, 8** | 36 | | |
| Species V correct | 1 |
| Species W correct | 1 |
| Species X correct | 1 |
| Species Y correct | 1 |
| Species Z correct | 1 |
| **Total** | **5** |

(b) Define an isotope. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Atoms of the same element with different number of neutrons. | 1 |
| **Total** | **1** |

(c) Define an ion and describe the difference between how cations and anions form. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Ions are charged species / Ions are atoms or groups of atoms with a charge. | 1 |
| Cations are formed when a species loses one or more electrons to become positively charged. | 1 |
| Anions are formed when a species gains one or more electrons to become negatively charged. | 1 |
| **Total** | **3** |

**Question 30 (8 marks)**

(a) Define the term ‘allotrope’. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Different structural forms of an element. | 1 |
| **Total** | **1** |

(b) Explain why graphite can conduct electricity, but when it is converted into Lonsdaleite it cannot. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| In graphite, each carbon atom is bonded to 3 other carbon atoms. | 1 |
| The fourth electron of each carbon atom is delocalised, providing mobile charge which can conduct an electrical current. | 1 |
| In Lonsdaleite, each carbon atom is bonding to 4 other carbon atoms. | 1 |
| Therefore all electrons are localised and there is no mobile charge which can carry an electrical current. | 1 |
| **Total** | **4** |

(c) Identify what makes fullerenes different from the other allotropes of carbon such as graphite, diamond and Lonsdaleite. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| They are nanomaterials.  **or**  The carbon atoms are connected to form a mesh (which can be open or closed) with rings of 5-7 atoms. | 1 |
| **Total** | **1** |

(d) State two (2) examples of fullerenes. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two of the following:   * buckyballs / buckminsterfullerene * buckytubes * carbon nanotubes * carbon nanobuds * carbon nano-onions * carbon megatubes | 2 |
| **Total** | **2** |

**Question 31 (5 marks)**

(a) Determine the molecular mass of phenanthrene. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 94.34 = 100 x (14 x 12.01) / M | 1 |
| M(phenanthrene) = (100 / 94.34) x 14 x 12.01  = 178.23 g mol-1 | 1 |
| **Total** | **2** |

(b) Determine the molecular formula of phenanthrene. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| M(total H) = 178.228 – (14 x 12.01)  = 10.088 | 1 |
| Number of H = 10.088 / 1.008  = 10 | 1 |
| MF(phenanthrene) is C14H10 | 1 |
| **Total** | **3** |

**Question 32 (9 marks)**

(a) Write a chemical equation showing how 2,3-dibromopentane could be produced by an addition reaction. Use structural formulae. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  |  |
| Correct reactants | 1 |
| Correct products | 1 |
| **Total** | **2** |
| Note: other possible answers include, for example, the addition reaction of  3,4-dibromopent-1-ene with hydrogen gas. | |

(b) Write chemical equations for a two-step process showing how 2,3-dibromopentane could be produced by a substitution reaction. Use structural formulae. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| **Step 1** |  |
| Correct reactants | 1 |
| Correct products | 1 |
| UV catalyst | 1 |
| **Step 2** |  |
| Correct species | 1 |
| **Total** | **4** |
| Note:   * Accept formation of either 2-bromopentane or 3-bromopentane in Step 1. * UV catalyst is not required in Step 2 for mark to be awarded. | |

(c) Explain why the addition reaction pathway is a superior choice for synthesising 2,3-dibromopentane, compared to the substitution pathway. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| In an addition reaction, it is certain that a bromine atom will be incorporated either side of the double carbon-carbon bond. | 1 |
| In a substitution reaction, the bromine atoms can replace any hydrogen atom. | 1 |
| Substitution would therefore result in a mixture of products.  **or**  It would be impossible to specifically produce 2,3-dibromopentane via a substitution reaction.  **or**  An addition reaction ensures only the 2,3-dibromopentane product is synthesised. | 1 |
| **Total** | **3** |

**Question 33 (9 marks)**

(a) Classify this reaction as endothermic or exothermic. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Endothermic | 1 |
| **Total** | **1** |

(b) Use the Law of Conservation of Energy to explain what caused the observed temperature change. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The system has taken heat in from the surroundings | 1 |
| and transformed the heat into enthalpy. | 1 |
| The total amount of energy is conserved.  **or**  The energy lost from the surroundings is equal to the energy gained by the system. | 1 |
| **Total** | **3** |

(c) Which enthalpy change diagram (i.e. A or B) could be used to represent this reaction? (circle your choice) (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Diagram B (circled) | 1 |
| **Total** | **1** |

(d) Describe how the processes of bond breaking and bond making relate to the sign of the enthalpy change in this reaction. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The energy required to break the bonds, | 1 |
| is greater than the energy released when new bonds are formed. | 1 |
| If there is an overall absorption of energy,  **or**  If the overall enthalpy of the products is greater than the reactants | 1 |
| then the enthalpy change has a positive sign. | 1 |
| **Total** | **4** |
| Alternate answer:   * Bond breaking is an endothermic process, whilst bond making is an exothermic process. * The enthalpy change is the difference in energy between these processes. * If a positive sign for the enthalpy change is used, * this indicates that overall, energy has been absorbed. | |

**Section Three: Extended answer 40% (86 marks)**

**Question 34 (13 marks)**

(a) Provide a reason that justifies why points 1 and 2 above are no longer considered to be accurate. (2 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 1. Atoms can be divided into subatomic particles | 1 |
| 2. Elements have different isotopes | 1 |
| **Total** | **2** |

(b) Name the model proposed by Thomson. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Plum pudding model | 1 |
| **Total** | **1** |

(c) Explain why the emission spectrum of hydrogen has more than one line, despite hydrogen atoms having only one electron. Your answer should include a brief description of how an emission spectrum is produced. (5 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Electrons absorb energy and jump to higher energy levels (becoming excited). | 1 |
| Electrons release this energy when they fall back down (to the ground state). | 1 |
| The energy released creates a unique emission spectrum. | 1 |
| A single electron has many different options for which energy levels it can move between. | 1 |
| Each different movement or ‘jump’ corresponds to a different frequency / energy / wavelength, and thus a different line on the spectrum. | 1 |
| **Total** | **5** |

(d) Draw a labelled diagram of an atom of oxygen-18. Your diagram should show all subatomic particles and incorporate Bohr’s theory on energy levels. (5 marks)

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
|  | 8 protons in nucleus | 1 |
| 10 neutrons in nucleus | 1 |
| 8 electrons in cloud | 1 |
| Electrons in configuration 2, 6 | 1 |
| Appropriately labelled | 1 |
| **Total** | **5** |

**Question 35 (14 marks)**

(a) Complete the table above, by writing the IUPAC name of each compound. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 2,2,4-trimethylpentane | 1 |
| 1-ethyl-3-methylbenzene / 3-ethyl-1-methylbenzene | 1 |
| (trans-)but-2-ene | 1 |
| **Total** | **3** |

(b) Describe two (2) differences between a fossil fuel and a biofuel. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two of the following points regarding fossil fuels:   * They are non-renewable * They take millions of years to produce * They are formed from the fossilised remains of plants and animals * They have a higher carbon footprint, as when burnt they release carbon into the atmosphere that has been trapped long ago | 2 |
| Any two of the following points regarding biofuels:   * They are renewable * They can be replenished in short time frame * They are formed from biological (plant/animal) material * They have a lower carbon footprint, as the carbon they release when burnt was previously taken in from the atmosphere during photosynthesis | 2 |
| **Total** | **4** |

(c) Complete the table on the previous page, by calculating the corresponding values for octane. The space below should be used to show any workings. Final values should be stated in the table. (7 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  |  |  | | --- | --- | --- | --- | --- | |  | Heat of combustion | Energy content | Mass of CO2(g) produced per gram of fuel combusted | Mass of CO2(g) produced per megajoule (MJ) of energy produced | | Ethanol | 1367 kJ mol-1 | 29.7 kJ g-1 | 1.91 g | 64.4 g | | Octane | **5460 kJ mol-1** | **47.8 kJ g-1** | **3.08 g** | **64.5 g** | |  |
| Heat of combustion | 1 |
| Energy content | 2 |
| Mass of CO2(g) produced per gram of fuel combusted | 2 |
| Mass of CO2(g) produced per megajoule (MJ) of energy produced | 2 |
| **Total** | **7** |
| Example of workings:  Heat of combustion = 10920 / 2 = 5460 kJ mol-1  n(octane in 1g) = 1 / 114.224 = 0.008755 mol  Energy content = 0.008755 x 5460 = 47.8 kJ g-1  n(CO2 from 1g octane) = (16/2) x 0.008755 = 0.07004 mol  m(CO2 from 1g octane) = 0.07004 x 44.01 = 3.082 g  n(CO2 for 1 MJ) = 1000 / 10920 x 16 = 1.4652 mol  m(CO2 for 1 MJ) = 1.4652 x 44.01 = 64.5 g | |

**Question 36 (16 marks)**

(a) Identify the separation technique that was used at Steps A, B and C, as shown in the diagram above, and state the physical property upon which that separation technique is based. (6 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| |  |  |  | | --- | --- | --- | |  | Separation technique | Physical property upon which separation depends | | Step A | **sieving / remove manually** | **particle size** | | Step B | **filtration** | **solubility** | | Step C | **distillation** | **different boiling points** | | 6 |
| **Total** | **6** |

(b) Explain, in terms of structure and bonding, why sand is not soluble in water. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Sand is a covalent network substance. | 1 |
| The extensive covalent bonding is very strong and cannot be disrupted easily. | 1 |
| There are no significant forces that can form between water and sand.  **or**  The intermolecular forces in water are not strong enough to disrupt the covalent network bonding in the sand. | 1 |
| **Total** | **3** |

(c) Explain, in terms of structure and bonding, why the contents of Beaker X would conduct electricity, whereas the contents of Beaker Y would not. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Beaker X contains seawater which would have dissolved salts/ions. | 1 |
| These dissolved ions constitute mobile charge, allowing the solution to conduct electricity. | 1 |
| Beaker Y contains pure water, which is a covalent molecular substance. | 1 |
| Therefore it would not contain any mobile charged particles, and would not be able to conduct electricity. | 1 |
| **Total** | **4** |

(d) Calculate the total number of gold atoms that would have been present. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(Au in 425 g) = 1 / (100 x 106 x 106) x 425  = 4.25 x 10-12 g | 1 |
| n(Au) = 4.25 x 10-12 / 197  = 2.1574 x 10-14 mol | 1 |
| N(Au) = 2.1574 x 10-14 x 6.022 x 1023  = 1.30 x 1010 atoms | 1 |
| **Total** | **3** |

**Question 37 (16 marks)**

(a) Calculate the total mass of carbon dioxide gas that would be produced in the smelting of this sample of ore. (8 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Converting tonnes to grams; 3.79 t = 3.79 x 106 g | 1 |
| m(Fe2O3) = (82.8/100) x 3.79 x 106  = 3.138 x 106 g | 1 |
| m(SiO2) = (15.1/100) x 3.79 x 106  = 5.723 x 105 g | 1 |
| n(Fe2O3) = 3.138 x 106 / 159.7  = 19650 mol | 1 |
| n(SiO2) = 5.723 x 105 / 60.09  = 9523.9 mol | 1 |
| n(CO2 from Fe2O3) = (3/2) x 19650  = 29475 mol  n(CO2 from SiO2) = 9523.9 mol | 1 |
| n(CO2 total) = 29475 + 9523.9  = 38999 mol | 1 |
| m(CO2 total) = 38999 x 44.01  = 1716341 g  = 1.72 t | 1 |
| **Total** | **8** |

(b) Explain, in terms of the structure and bonding present in iron, how each of these properties arise. (4 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| High melting point |  |
| There is a strong electrostatic attraction between the delocalised sea of electrons and the metal cations. | 1 |
| Therefore a large amount of heat is required to disrupt this bonding. | 1 |
| Malleable |  |
| The bonding between the delocalised electrons and metal cations is non-directional. | 1 |
| Therefore when a force is applied, the iron can change shape without disrupting the bonding. | 1 |
| **Total** | **4** |

(c) Define a nanoparticle. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| A particle whose size is within the range 1-100 nm | 1 |
| **Total** | **1** |

(d) Explain how the incorporation of nanoparticles in the coating material provides superior corrosion resistance. (3 marks)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The smaller size of the nanoparticles means that more particles can interact with the surface of the iron. | 1 |
| This forms a more complete coating (than would occur in the absence of nanoparticles). | 1 |
| This reduces the contact between the iron and oxygen and/or water, minimising the chance of rusting. | 1 |
| **Total** | **3** |