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**CHEMISTRY**

**UNIT 1**

**2023**

**MARKING GUIDE**

***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 | 20 | 20 | 40 | 20 | 25 |
| Section Two  Short answer | 7 | 7 | 50 | 60 | 35 |
| Section Three  Extended answer | 5 | 5 | 60 | 75 | 40 |
|  |  |  |  | **Total** | 100 |

**Section One: Multiple-choice 25% (20 marks)**

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 1 | a □ b ■ c □ d □ |  | 6 | a ■ b □ c □ d □ |  |  |  |
| 2 | a ■ b □ c □ d □ |  | 7 | a □ b ■ c □ d □ |  |  |  |
| 3 | a □ b □ c □ d ■ |  | 8 | a □ b ■ c □ d □ |  |  |  |
| 4 | a ■ b □ c □ d □ |  | 9 | a □ b □ c ■ d □ |  |  |  |
| 5 | a □ b □ c ■ d □ |  | 10 | a □ b □ c □ d ■ |  |  |  |

|  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- |
| 11 | a □ b ■ c □ d □ |  | 16 | a □ b □ c ■ d □ |  |  |  |
| 12 | a □ b □ c □ d ■ |  | 17 | a □ b □ c ■ d □ |  |  |  |
| 13 | a □ b ■ c □ d □ |  | 18 | a ■ b □ c □ d □ |  |  |  |
| 14 | a □ b □ c □ d ■ |  | 19 | a ■ b □ c □ d □ |  |  |  |
| 15 | a ■ b □ c □ d □ |  | 20 | a □ b ■ c □ d □ |  |  |  |

**Section Two: Short answer 35% (60 marks)**

**Question 21 (6 marks)**

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

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| aluminium fluoride | **AlF3** | 1 |
| **ammonia** | NH3 | 1 |
| dibromine monoxide | **Br2O** | 1 |
| potassium ethanoate | **KCH3COO / CH3COOK** | 1 |
| **iron(III) carbonate** | Fe2(CO3)3 | 1 |
| phosphoric acid | **H3PO4** | 1 |
| **Total** | | **6** |

**Question 22 (7 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Four | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| All isotopes would have 24 protons. | 1 |
| All isotopes would have 24 electrons. | 1 |
| Isotopes would have either 26, 28, 29 or 30 neutrons. | 1 |
| **Total** | **3** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The average mass of an atom compared to 1/12th the mass of an atom of carbon-12. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Ar = (4.35 x 50 + 83.78 x 52 + 9.5 x 53 + 2.37 x 54) / 100 | 1 |
| = 52.06 | 1 |
| **Total** | **2** |

**Question 23 (12 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Alkali metals. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| They have one valence electron. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Rubidium. | 1 |
| The valence electrons are further from the nucleus (and experience increased shielding) therefore they are less attracted / are held less tightly. | 1 |
| Thus rubidium has a lower first ionisation energy. | 1 |
| It will therefore lose / donate an electron more readily (resulting in higher reactivity). | 1 |
| **Total** | **4** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Halogens. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| They react to gain / accept one electron (to obtain a stable octet). | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Chlorine. | 1 |
| The valence electrons are closer to the nucleus (and experience less shielding) therefore they are more attracted / are held more tightly. | 1 |
| Thus chlorine has a higher electronegativity. | 1 |
| It will therefore attract / gain an electron more readily (resulting in higher reactivity). | 1 |
| **Total** | **4** |

**Question 24 (8 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Nanoparticles must be in the size range 1-100 nm. | 1 |
| Nanorods are within this range, but supraparticles are too big. | 1 |
| **Total** | **2** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any appropriate similarity, including:   * Comprised of the same type of atom * Composed of a metal element * Metallic bonding * Can be shaped/malleable | 1 |
| Any appropriate difference, including:   * Colour * Electrical conductivity * Melting point * Reactivity | 1 |
| **Total** | **2** |

(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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(aflatoxin B1 in 1 mL) = 0.16 ng  = 0.16 x 10-9 g | 1 |
| M(aflatoxin B1) = 312.266 g mol-1 | 1 |
| n(aflatoxin B1) = 0.16 x 10-9 / 312.266  = 5.1238 x 10-13 mol | 1 |
| N(aflatoxin B1) = 5.1238 x 10-13 x 6.022 x 1023  = 3.086 x 1011 molecules | 1 |
| **Total** | **4** |

**Question 25 (11 marks)**

(a) What is an ‘alkane’? (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| A hydrocarbon with only single bonds between carbon atoms. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Fractional distillation. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Different boiling points. | 1 |
| **Total** | **1** |

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

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
|  | **3,4-dibromo-1-fluorohexane** | 2 |
|  | **2,3,5-trimethyloct-2-ene** | 2 |
|  | 3-chloropropene | 2 |
|  | 1-iodo-2-methylbutane | 2 |
| **Total** | | **8** |
| **Note:**  One mark may be allocated in each case, if a minor error is included.  Examples of a *naming* minor error include not alphabetising side groups.  Example of a *drawing* minor error include a missing / extra H atom. | | |

**Question 26 (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.

|  |  |
| --- | --- |
| **Description** | **Marks** |
| 2 C4H10(l) + 13 O2(g) → 8 CO2(g) + 10 H2O(g) | 1 |
| 2 C5H10(l) + 15 O2(g) → 10 CO2(g) + 10 H2O(g) | 1 |
| n(CO2) = 784 / 44.01  = 17.814 mol | 1 |
| n(C4H10) = (2/8) x 17.814  = 4.4535 mol | 1 |
| n(C4H10) = 4.4535 x 58.12  = 259 g | 1 |
| n(C5H10) = (2/10) x 17.814  = 3.5628 mol | 1 |
| m(C5H10) = 3.5628 x 70.13  = 250 g | 1 |
| Statement supporting that the fuel used was pentene, for example;   * A greater mass of butane would have been required to produce this much CO2 * The mass of CO2 produced corresponds to 250 g of pentene, not butane * A 250 g sample of butane would have produced only 757 g of CO2 | 1 |
| **Total** | **8** |
| **Alternate working:**  n(C4H10) = 250 / 58.12  = 4.3014 mol  n(CO2) = (8/2) x 4.3014  = 17.206 mol  m(CO2) = 17.206 x 44.01  = 757 g  n(C5H10) = 250 / 70.13  = 3.565 mol  n(CO2) = (10/2) x 3.565  = 17.824 mol  m(CO2) = 17.824 x 44.01  = 784 g  **Note:**  State symbols are not required in equations. | |

**Question 27 (8 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The valence electrons of both reside in the third shell. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Magnesium atoms lose 2 electrons. | 1 |
| Sulfur atoms gain 2 electrons. | 1 |
| Mg2+ cations and S2- anions are formed. | 1 |
| Oppositely charged ions are electrostatically attracted to one another (forming ionic bonds). | 1 |
| **Total** | **4** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Magnesium sulfide consists of a rigid 3D lattice composed of ions. | 1 |
| When a force is applied this causes like charges to align / causes disruption of the lattice structure. | 1 |
| The similarly charged ions then repel, causing the lattice to shatter. | 1 |
| **Total** | **3** |

**Section Three: Extended answer 40% (75 marks)**

**Question 28 (11 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Substitution. | 1 |
| Several acceptable justifications, including:   * Toluene has no double bonds thus cannot undergo addition * Two products are formed in this reaction * Only one product would be formed if it was addition * The H atoms on toluene are substituted for NO2 groups * Nitration occurs in a successive/stepwise manner | 1 |
| **Total** | **2** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(HNO3) = 385 x 103 g | 1 |
| n(HNO3) = 385000 / 63.018  = 6109.37 mol | 1 |
| n(TNT) = (1/3) x 6109.37  = 2036.46 mol | 1 |
| M(TNT) = 227.14 g mol-1 | 1 |
| m(TNT) = 2036.46 x 227.14  = 462560 g | 1 |
| = 463 kg **or** 4.63 x 105 g | 1 |
| **Total** | **6** |

(c) Identify whether this reaction is endothermic or exothermic. (1 mark)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Exothermic. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| The total quantity of energy is conserved in the reaction. | 1 |
| One of the following explanations:   * The energy released as heat is equal to the decrease in enthalpy of the products compared to the reactants.   **or**   * The energy lost by the system is equal to the energy gained by the surroundings.   **or**   * The enthalpy lost by the system is equal to the heat released to the surroundings. | 1 |
| **Total** | **2** |

**Question 29 (15 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Electrons can absorb energy. | 1 |
| This causes the electrons to move to higher energy levels / become excited. | 1 |
| When the electrons fall back to lower energy levels / return to ground state, | 1 |
| energy is released as (photons of) light (creating an emission spectrum). | 1 |
| **Total** | **4** |

(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)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| (The emission spectrum from the lamp matches that of the metal being analysed) in order for the metal to be able to absorb those particular frequencies/wavelengths/photons of light. | 1 |
| The level of absorption is then proportional to the concentration of the metal present. | 1 |
| **Total** | **2** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Primary | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Several acceptable answers, including;   * Ensures the data collected reflects the levels of the metals present in gunshot residue only (rather than the total amount of metals present in the environment). * Measuring background levels shows the method used by the scientist directly relates to the aim (i.e. to determine the quantity of metals present in gunshot residue). * Ensures the independent variable (gunshot residue) is the only variable contributing to the dependent variable (quantity of metals present). * Demonstrates that the scientist has ensured that controlled variables are controlled. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Several acceptable answers, including;   * Allows the consistency of results to be monitored. * Allows outliers to be identified (and removed if necessary). * Averaging reduces the effect of random errors on the data. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Several acceptable answers, including;   * May be used evidence in a court. * Could affect the outcome/result of a trial. * A person may be sentenced based on this data. | 1 |
| **Total** | **1** |

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

|  |  |  |
| --- | --- | --- |
| **Description** | | **Marks** |
| Lead | accept values in the range 2.2 to 4.0 ppm | 1 |
| Antimony | accept values in the range 0.35 to 0.45 ppm | 1 |
| Barium | accept values in the range 1.62 to 1.80 ppm | 1 |
| All values stated to appropriate degree of precision  (i.e. 1 dp for Pb and 2 dp for Sb and Ba) | | 1 |
| **Total** | | **4** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Bullet A | 1 |
| **Total** | **1** |

**Question 30 (15 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
|  |  |
| Appropriate title | 1 |
| Appropriate scale on y-axis | 1 |
| Appropriate label on y-axis | 1 |
| Points plotted correctly | 1 |
| Curve of best fit | 1 |
| **Total** | **5** |

(b) 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)

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Lead and tin are elements / pure substances, | 1 |
| thus have fixed/distinct measurable properties. | 1 |
| Solder is a mixture, | 1 |
| thus its properties are dependent upon its composition. | 1 |
| **Total** | **4** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Metals contain delocalised electrons. | 1 |
| These delocalised electrons act as mobile charge carriers. | 1 |
| **Total** | **2** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| m(Sn in 3 mol) = 3 x 118.7  = 356.1 g | 1 |
| m(Pb in 1 mol) = 1 x 207.2  = 207.2 g | 1 |
| %Sn = (356.1 / 563.3) x 100  = 63.22 % | 1 |
| %Pb = (207.2 / 563.3) x 100  = 36.78 % | 1 |
| **Total** | **4** |

**Question 31 (14 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Biofuels are produced from renewable resources / from plant (or animal) based raw materials. | 1 |
| Fossil fuels are produced from non-renewable resources / from fossilised raw materials produced over millions of years. | 1 |
| **Total** | **2** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Several acceptable answers, including;   * Lower carbon footprint / lower carbon emissions. * Reduce the amount of greenhouse gases. * Reduce global warming. * Increased sustainability. * Upholds the principles of green chemistry. * Can contribute to moving towards a circular economy. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Several acceptable answers, including;   * Infrastructure may not be available / in place to produce biofuels. * Not always affordable. * Some biofuels are not ‘drop in’ fuels, thus harder to incorporate into existing systems. * Requires political will to change to a greener economy. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Several acceptable answers, including;   * Utilises a waste product rather than a food source. * Prevents food crops being diverted for conversion into fuels. | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| n(1 g ethanol) = 1 / 46.068  = 0.021707 mol | 1 |
| n(O2 required) = 3 x 0.021707  = 0.065121 mol | 1 |
| m(O2) = 0.065121 x 32  = 2.0839 g | 1 |
| m(air) = 2.0839 x (100/21)  = 9.92 g | 1 |
| Thus air-fuel ratio is 9.92. | 1 |
| **Total** | **5** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Energy density = 42.9 x 0.7446  = 31.94 MJ L-1 | 1 |
| Thus petrol has the highest energy density. | 1 |
| **Total** | **2** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Petrol is not a pure substance / Petrol is a mixture. | 1 |
| Therefore it does not have an exact molar mass / Therefore an exact number of moles cannot be calculated. | 1 |
| **Total** | **2** |

**Question 32 (20 marks)**

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| crystal  wires  battery / power source  ammeter / globe  A |  |
| Appropriate circuit components sketched | 1 |
| Inclusion of a globe or ammeter in circuit | 1 |
| Labels on diagram | 1 |
| **Total** | **3** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Graphite. | 1 |
| Each carbon atom in graphite uses three of its valence electrons to form covalent bonds to three other carbon atoms. | 1 |
| The fourth valence electron of each carbon atom is delocalised and can conduct electricity. | 1 |
| **Total** | **3** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Sucrose. | 1 |
| It is a covalent molecular substance / It exists as discrete molecules. | 1 |
| It exhibits only weak intermolecular forces. | 1 |
| Thus only a small amount of heat is required to disrupt the bonding. | 1 |
| **Total** | **4** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Diamond. | 1 |
| It is a covalent network structure. | 1 |
| The strong covalent bonds that extend throughout the 3D network cannot easily be broken (and thus diamond is not soluble). | 1 |
| **Total** | **3** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| NaCl(aq)  **or**  Na+(aq) and Cl-(aq)  **or**  NaCl(s) → Na+(aq) + Cl-(aq) | 1 |
| **Total** | **1** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| When solid, the ions are in fixed positions within the lattice. | 1 |
| Thus no mobile charge carriers are present (and therefore the substance is unable to conduct electricity). | 1 |
| When dissolved, the ions dissociate.  **or**  NaCl(s) → Na+(aq) + Cl-(aq) | 1 |
| Therefore freely moving ions are present in solution which are able to conduct an electrical current. | 1 |
| **Total** | **4** |

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

|  |  |
| --- | --- |
| **Description** | **Marks** |
| Any two (2) acceptable answers, including;   * Hot plate may cause burns. * Hot plate may ignite a fire. * Risk of electrocution. * Electrical circuits can generate heat / ignite fires. | 2 |
| **Total** | **2** |