CHEMISTRY
UNIT 1
2022

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

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

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

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

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

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**

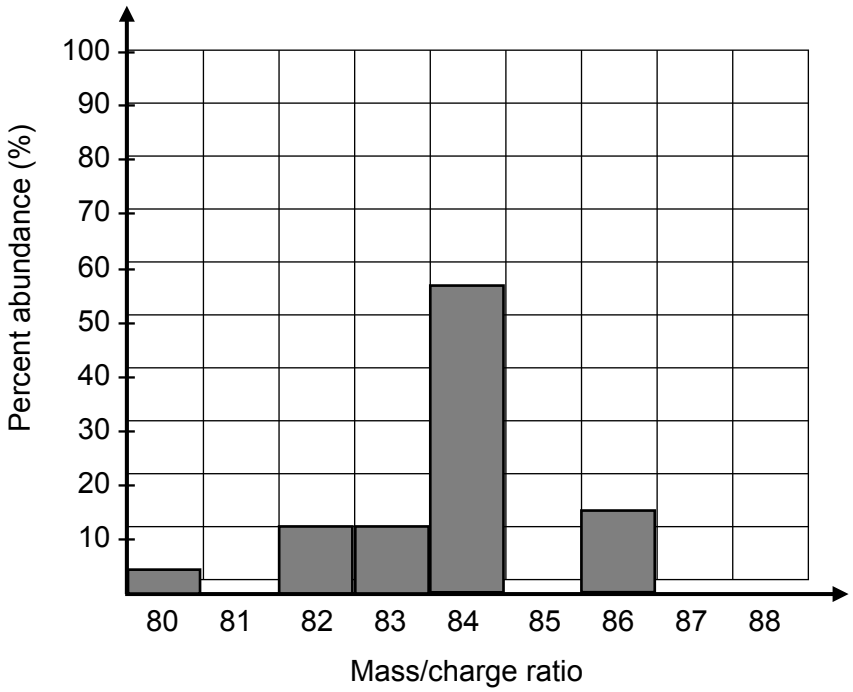
Question 27 **(5 marks)**

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	1
	=	0.764 g	
m(carbenicillin each day)	=	0.764 x 4	1
	=	3.056 g	
M(carbenicillin)	=	378.394 g mol^{-1}	1
n(carbenicillin)	=	3.056 / 378.394	1
	=	0.00807624 mol	
N(carbenicillin)	=	0.00807624 x (6.022×10^{23})	1
	=	4.86×10^{21} molecules	
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
	
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
A_r	=	(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 **(6 marks)**

(a) Consider the **bolded** section of Step 1. Explain how this would have decreased the validity of this analysis. (2 marks)

Description	Marks
Variables are not being controlled.	1
An appropriate statement relating to this error, including: • All samples should be diluted in the same solvent • Tap water may contain impurities which can affect the data • Different solvents may affect the background absorbance reading	1
Total	**2**

(b) Consider the **bolded** section of Step 4. Explain how this would have increased the reliability of this analysis. (2 marks)

Description	Marks
Any two of the following: • Allows averages to be calculated • Reduces the effect of random error • Allows outliers to be removed from the data set	2
Total	**2**

(c) Has the chemist collected primary or secondary data? Justify your choice. (2 marks)

Description	Marks
Primary	1
Chemist personally collected the data	1
Total	**2**

Question 31 **(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 32 **(5 marks)**

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

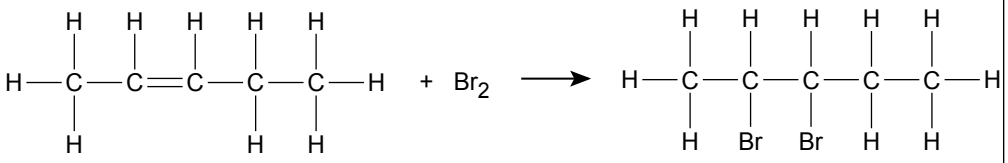
Description	Marks
94.34 = 100 x (14 x 12.01) / M	1
M(phenanthrene) = (100 / 94.34) x 14 x 12.01 = 178.23 g mol^{-1}	1
Total	**2**

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

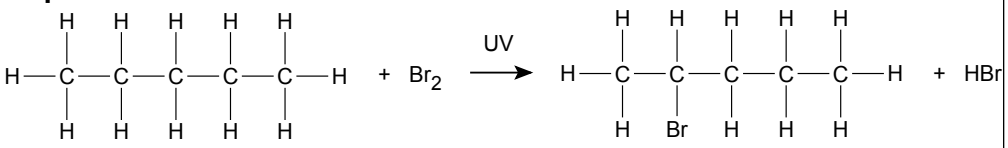
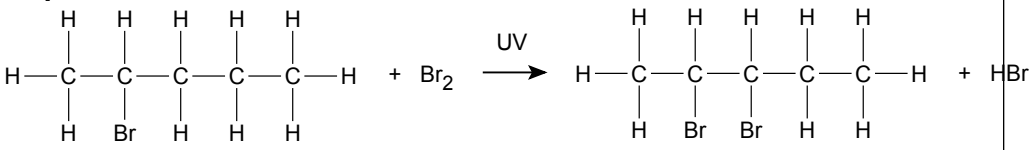
Description	Marks
M(total H) = 178.228 – (14 x 12.01) = 10.088	1
Number of H = 10.088 / 1.008 = 10	1
MF(phenanthrene) is $C_{14}H_{10}$	1
Total	**3**

Question 33 **(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 34 **(9 marks)**

(a) Write a balanced molecular equation for this chemical reaction. (3 marks)

Description	Marks
$Al_2(SO_3)_3(s) + 6\ HNO_3(aq) \rightarrow 3\ H_2O(l) + 3\ SO_2(g) + 2\ Al(NO_3)_3(aq)$	
Correct reactants	1
Correct products	1
Correct balancing	1
Total	**3**
Note: state symbols are not required for full marks.	

(b) Write a balanced ionic equation for this reaction. (1 mark)

Description	Marks
$Al_2(SO_3)_3(s) + 6\ H^+(aq) \rightarrow 3\ H_2O(l) + 3\ SO_2(g) + 2\ Al^{3+}(aq)$	
Correct equation	1
Total	**1**
Note: state symbols are not required for full marks.	

(c) Calculate the percentage purity of the aluminium sulfite powder. State your answer to the appropriate number of significant figures. (5 marks)

Description			Marks
$n(SO_2)$	=	0.97 / 64.06 0.015142 mol	1
$n(Al_2(SO_3)_3)$	=	(1/3) x 0.015142 0.0050474 mol	1
$m(Al_2(SO_3)_3)$	=	0.0050474 x 294.14 1.4846 g	1
% purity	=	1.4846 / 1.82 x 100 81.57%	1
	=	82% (2 SF)	1
		Total	**5**
Note: follow through marks may be awarded if correct calculation method is shown based on an incorrect equation in part a) / b)			

Question 35 **(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 36 **(18 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**

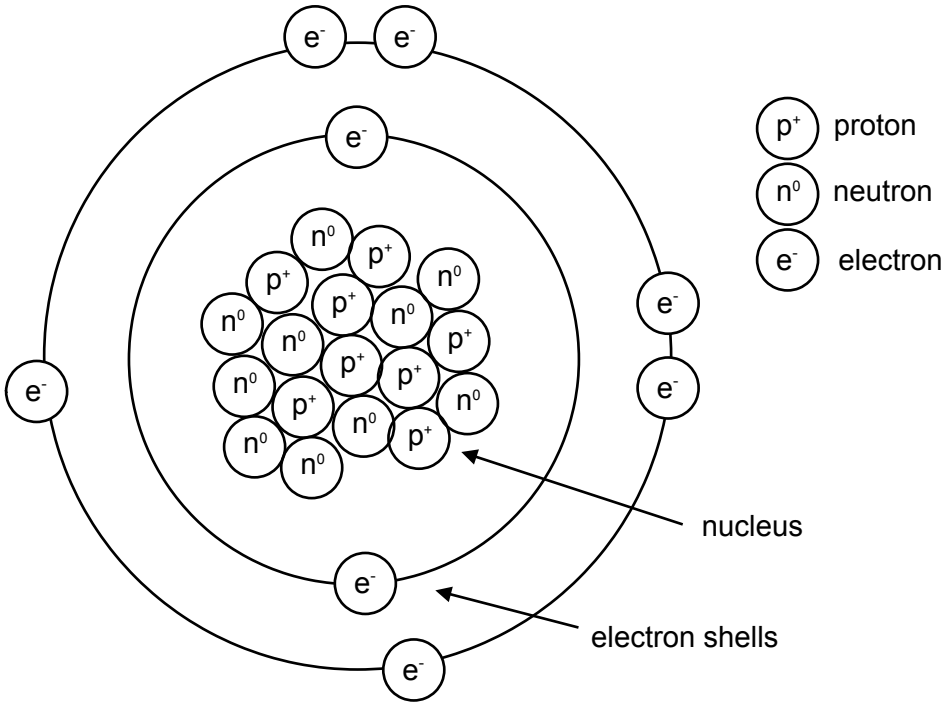
(c) Briefly describe the 'gold foil experiment' conducted by Rutherford and the corresponding conclusions he drew about atomic structure. (5 marks)

Description	Marks
He fired (alpha) particles at a thin sheet of gold.	1
It was observed that most particles passed through the gold sheet,	1
whilst some were deflected.	1
He concluded that atoms consisted mostly of empty space,	1
with a central nucleus containing most of the mass.	1
Total	**5**

(d) 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**

(e) 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 37 **(17 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
<table><tr><th></th><th>Heat of combustion</th><th>Energy content</th><th>Mass of $CO_2(g)$ produced per gram of fuel combusted</th><th>Mass of $CO_2(g)$ produced per megajoule (MJ) of energy produced</th></tr><tr><td>Ethanol</td><td>1367 kJ mol^{-1}</td><td>29.7 kJ g^{-1}</td><td>1.91 g</td><td>64.4 g</td></tr><tr><td>Octane</td><td>**5460 kJ mol^{-1}**</td><td>**47.8 kJ g^{-1}**</td><td>**3.08 g**</td><td>**64.5 g**</td></tr></table>	
Heat of combustion	1
Energy content	2
Mass of $CO_2(g)$ produced per gram of fuel combusted	2
Mass of $CO_2(g)$ 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(CO_2 from 1g octane) = (16/2) x 0.008755 = 0.07004 mol m(CO_2 from 1g octane) = 0.07004 x 44.01 = 3.082 g n(CO_2 for 1 MJ) = 1000 / 10920 x 16 = 1.4652 mol m(CO_2 for 1 MJ) = 1.4652 x 44.01 = 64.5 g	

(d) Construct an argument for the use of ethanol as a vehicle fuel, by identifying three (3) advantages of ethanol over octane. (3 marks)

Description	Marks
Any three of the following: • lower carbon footprint • lower CO_2 emitted per gram of fuel • more sustainable • less environmental destruction • reduce effects of climate change • supports the principles of green chemistry • produced from renewable resources	3
Total	**3**

Question 38 **(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	6
Step A	**sieving / remove manually**	**particle size**	
Step B	**filtration**	**solubility**	
Step C	**distillation**	**different boiling points**	
		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)	=	$1 / (100 \times 10^{6} \times 10^{6}) \times 425$	1
	=	4.25×10^{-12} g	
n(Au)	=	$4.25 \times 10^{-12} / 197$	1
	=	2.1574×10^{-14} mol	
N(Au)	=	$2.1574 \times 10^{-14} \times 6.022 \times 10^{23}$	1
	=	1.30×10^{10} atoms	
		Total	**3**

Question 39 **(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 = 3.79×10^6 g			1
$m(Fe_2O_3)$	=	(82.8/100) x 3.79×10^6	1
	=	3.138×10^6 g	
$m(SiO_2)$	=	(15.1/100) x 3.79×10^6	1
	=	5.723×10^5 g	
$n(Fe_2O_3)$	=	3.138×10^6 / 159.7	1
	=	19650 mol	
$n(SiO_2)$	=	5.723×10^5 / 60.09	1
	=	9523.9 mol	
$n(CO_2$ from $Fe_2O_3)$	=	(3/2) x 19650	1
	=	29475 mol	
$n(CO_2$ from $SiO_2)$	=	9523.9 mol	
$n(CO_2$ total)	=	29475 + 9523.9	1
	=	38999 mol	
$m(CO_2$ total)	=	38999 x 44.01	1
	=	1716341 g	
	=	1.72 t	
		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**

Question 40 **(19 marks)**

(a) Explain, in terms of electron behaviour, why sodium and chlorine react to form an ionic bond. Your answer should refer to both ionisation energy and electronegativity. (6 marks)

Description	Marks
Sodium has a low ionisation energy, meaning it will lose electrons easily.	1
Chlorine has a high electronegativity, meaning it exerts a strong pull on electrons.	1
In the formation of an ionic bond, electrons are transferred from sodium to chlorine.	1
This results in a stable octet electron configuration for each species.	1
The sodium becomes positively charged and the chlorine negatively charged.	1
The oppositely charged ions are then electrostatically attracted to one another, forming an ionic bond.	1
Total	**6**

(b) Calculate the value of the enthalpy change for this process, and then write a balanced thermochemical equation for this reaction, incorporating this value. (7 marks)

Description	Marks
n(Na) = 4.81 / 22.99 = 0.20922 mol	1
Enthalpy change: ΔH = - 86.0 / 0.20922 = - 411 kJ mol^{-1}	
Correct value	1
Assigning a negative value to ΔH	1
Thermochemical equation: $2\ Na(l) + Cl_2(g) \rightarrow 2\ NaCl(s) + 822\ kJ$	
Correct species	1
Correct balancing	1
Heat shown on product side	1
Value of ΔH doubled to reflect stoichiometric ratio in the equation	1
Total	**7**

(c) Identify two (2) safety risks associated with carrying out this reaction in the laboratory, and suggest a specific safety measure required to minimise each of these risks. (4 marks)

Description	Marks
Any two of the following safety risks: • Chlorine gas is toxic • Sodium can react with the moisture in skin/eyes and cause burns • Risks associated with heat of flame, e.g. burns • Risks associated with bright light produced	2
Any **related** safety measures, including: • Ensure appropriate ventilation / ensure safe storage of chlorine • Ensure chlorine is not inhaled / wear gas mask / perform in fumehood etc • Keep sources of ignition at a safe distance / ensure no other flammable materials are in proximity • Prevent contact with sodium e.g. wear gloves / wear protective clothing / wear glasses • Protection from heat, e.g. wear gloves / wear protective clothing / wear glasses • Protection for bright light, e.g. wear glass / do not look directly at flame	2
Total	**4**

(d) If this reaction was carried out using fluorine, $F_2(g)$, instead of chlorine, predict how the value of the enthalpy change would be affected. Justify your answer. (2 marks)

Description	Marks
The value of H would have a greater magnitude / be more negative / reflect a larger release of energy.	1
$F_2(g)$ is more reactive / has a higher electronegativity.	1
Total	**2**