1 Which separation technique would be best to obtain samples of pure copper sulfate from a solution of copper sulfate?

(A) Evaporation
(B) Centrifugation
(C) Distillation
(D) Filtration

2 Alkali metals become more reactive proceeding down the Group. This is because:

(A) the energy produced in the ionisation of the metal atoms increases.
(B) the energy required to ionise the metal atoms increases.
(C) the energy produced in the ionisation of the metal atoms decreases.
(D) the energy required to ionise the metal atoms decreases.

3 Which of the following statements about bonding between molecules is true?

(A) Only molecules which have H-N, H-O or H-F bonds can produce dipole-dipole bonds.
(B) All molecules which have polar covalent bonds will produce either dipole-dipole or hydrogen bonds.
(C) The larger the molecules in a homologous series the stronger the dispersion forces.
(D) Non-polar molecules have no intermolecular bonds.

4 0.30 moles of magnesium nitrate is weighed out and then dissolved in water to an exact volume of 500 mL. Which of the following is correct?

(A) the concentration of nitrate ions is 0.30 mol L^{-1}
(B) the concentration of magnesium ions is 0.15 mol L^{-1}
(C) the concentration of nitrate ions is 1.2 mol L^{-1}
(D) the concentration of magnesium ions is 0.30 mol L^{-1}

5 Water is considered to have an unusually high specific heat capacity. What does this tell you about water?

(A) Compared to most other materials, a given mass of water will experience a larger temperature change per Joule of energy absorbed or released.
(B) Compared to most other materials, for a given mass of water, a great deal of energy could be absorbed with only a small change in temperature.
(C) Compared to most other materials, for a given body of water, a small amount of energy absorbed will result in a large temperature change.
(D) Compared to most other materials, a large mass of water would be required for a 1K temperature drop to cause a large release of energy.

6 Which of the following is true about endothermic reactions?

(A) They will always have a negative ΔH.
(B) The energy of the reactants will always be greater than that of the products.
(C) There will be a net gain of energy to the chemical system.
(D) Energy will be released in the breaking of bonds and absorbed in the formation of bonds.

7 Which of the following best describes the relationship of graphite and diamond?

(A) They are two isotopes of carbon.
(B) They are two isomers of carbon.
(C) They are two nucleons of carbon.
(D) They are two allotropes of carbon.

8 Which of the following species have the same electron configuration?

(A) F, Cl, Br
(B) Cl^-, Ar, K^+
(C) Na, Mg, Al
(D) Cu, Zn, Fe

9 Which of the following is a correct statement about molecules?

(A) The formula NaCl represents a molecule of sodium chloride.
(B) All covalently bonded substances are made of molecules.
(C) Only compounds can be molecular.
(D) A molecule is a finite structure composed of two or more covalently bonded atoms.

10 The formula for glucose is $C_6H_{12}O_6$. Which of the following is true for $C_6H_{12}O_6$?

(A) It is a molecular formula.
(B) It is a structural formula.
(C) It is an empirical formula.
(D) It is both an empirical and molecular formula.

11 The structure of a metallic lattice can best be described as:

(A) a 3D array of cations held together by a sea of electrons.
(B) a 3D array of alternating cations and anions.
(C) a 3D array of atoms covalently bonded to each other.
(D) a 3D array of dissociated atoms which are free to move around.

12 Which of the following substances has the **largest** molar mass?

(A) lithium sulfate
(B) beryllium sulfate
(C) sodium sulfate
(D) calcium sulfate

13 Which of the following contains the same number of **molecules** as there are **ions** in 1.000 mol of magnesium chloride?

(A) 64.14 g of solid sulfur
(B) 22.71 L of gaseous chlorine (measured at 0 °C and 100 kPa)
(C) 479.4 g of liquid bromine
(D) 49.58 L of gaseous argon (measured at 25 °C and 100 kPa)

14 When sodium reacts with excess oxygen, the major product is sodium peroxide (Na_2O_2). It is formed in accordance with the following balanced chemical equation:

$$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$$

What mass of sodium peroxide should be produced when 15.00 g of sodium reacts with excess oxygen?

(A) 12.72 g
(B) 25.44 g
(C) 36.55 g
(D) 50.87 g

15 2.000 g of barium chloride is dissolved in water and added to a solution containing excess silver nitrate. What mass of precipitate is formed?

(A) 1.377 g
(B) 1.718 g
(C) 2.510 g
(D) 2.754 g

16 The following table represents successive ionisation energies for Element Y and Element Z. One element is a metal and the other is a non-metal.

Element Y	Element Z
1,012	578
1,903	1,817
2,912	2,745
4,956	11,575
6,273	14,830
22,233	18,376
25,397	23,293

When the two elements were combined under the right conditions a synthesis reaction occurred. Using the data above, determine the correct formula for the resulting compound.

(A) ZY_2
(B) ZY
(C) Y_3Z_5
(D) ZY_3

17 Arrange Na, Al, Rb and Sr metals in order of increasing first ionisation energy:

(A) Na, Al, Rb, Sr
(B) Sr, Rb, Al, Na
(C) Al, Na, Sr, Rb
(D) Rb, Sr, Na, Al

18 Which of the following is true for all metal displacement reactions?

(A) Ions of the less reactive metal gain electrons from the atoms of the more reactive metal.
(B) Ions of the more reactive metal gain electrons from the atoms of the less reactive metal.
(C) Atoms of the more reactive metal gain electrons from the ions of the less reactive metal.
(D) Atoms of the less reactive metal gain electrons from the ions of the more reactive metal.

19 2 L of an unknown gas has the same mass as 0.5 L of bromine gas at the same temperature and pressure. What is the gas?

(A) CO_2
(B) Ne_2
(C) F_2
(D) Ar

20 Moving from left to right across Period 3 of the Periodic Table, which of the following does **not** increase?

(A) The number of electron shells
(B) The total number of electrons
(C) The number of valence electrons
(D) The charge on the nucleus

21 Which of the following elements has the highest electronegativity?

(A) helium
(B) francium
(C) fluorine
(D) nitrogen

22 Which of the following iron-containing minerals has the greatest percentage of iron by mass?

(A) magnetite, $Fe_3O_{4(s)}$
(B) hematite, $Fe_2O_{3(s)}$
(C) siderite, $FeCO_{3(s)}$
(D) goethite, $FeO(OH)_{(s)}$

23 Approximately how many atoms are there in 1.00 g of water?

(A) 3.34×10^{22}
(B) 1.00×10^{23}
(C) 6.02×10^{23}
(D) 1.81×10^{24}

24 Which of the following substances has the **smallest** molar mass?

(A) sodium oxide
(B) magnesium oxide
(C) potassium oxide
(D) calcium oxide

25 When comparing a more reactive metal with a less reactive metal:

(A) The less reactive metal is more likely to be found as an uncombined naturally occurring element.
(B) The more reactive metal is more spontaneous in losing electrons than is the less reactive metal.
(C) More energy is required to extract the less reactive metal from one of its compounds.
(D) More reactive metals absorb more heat than less reactive metals when they react.

26 Nitrogen trifluoride can be decomposed to form nitrogen and fluorine gas. Which of the following balanced equations correctly represents this reaction?

(A) $NF_{3(g)} \rightarrow N_{(g)} + F_{3(g)}$
(B) $2N_3F_{3(g)} \rightarrow 3N_2F_{2(g)}$
(C) $2NF_{3(g)} \rightarrow N_{2(g)} + 3F_{2(g)}$
(D) $NF_{3(g)} \rightarrow N_{(g)} + 3F_{(g)}$

27 Which of the following shows elements in increasing atomic mass?

(A) Cl, Ar, K, Ca,
(B) Zn, Cu, Ni, Co
(C) Cs, Rb, K, Na
(D) I, Te, Xe, Cs

28 In which of the following substances do strong chemical bonds **NOT** extend throughout the crystal lattice in the **solid** state?

(A) mercury
(B) iodine
(C) silicon dioxide
(D) sodium chloride

29 Using the solubility rules, determine which of the following combinations of solutions would form a precipitate.

(A) Magnesium sulfate and barium nitrate
(B) Barium chloride and sodium hydroxide
(C) Sodium carbonate and lithium nitrate
(D) Silver nitrate and potassium nitrate

30 Which of the following contains the same number of ions as 1 mole of aluminium chloride?

(A) 3 mole of sodium hydroxide
(B) 2 mole of barium carbonate
(C) 1 mole of ammonium nitrate
(D) 0.5 mole of ammonium sulfate

31 Consider the following atom, $^{17}_{8}O$. This atom contains:

(A) 8 protons, 8 electrons and 17 neutrons.
(B) 8 protons, 8 electrons and 9 neutrons.
(C) 9 protons, 9 electrons and 17 neutrons.
(D) 17 protons, 17 electrons and 8 neutrons.

32 Which of the following is the name for FeS?

(A) iron monosulfide
(B) iron monosulfate
(C) iron(II) sulfide
(C) iron(II) sulfate

33 Which of the following methods would best enable you to separate two immiscible liquids?

(A) using a separating funnel
(B) using a filter funnel
(C) using evaporation
(D) using distillation

34 Which compound contains both covalent and ionic bonds?

(A) $MgBr_2$
(B) $CHCl_3$
(C) BCl_3
(D) NH_4NO_3

35 An atom of element Z (not correct symbol) has the electronic configuration 2, 8, 6. Which of the following species is this element most likely to form?

(A) the ion Z^{2+}
(B) the ion Z^{6+}
(C) the compound H_2Z
(D) the compound Z_6F

36 The first four successive ionisation energies (measured in kJ mol^{-1}) for an element are 550, 1064, 4210 and 5500. This element should be placed in the same group as:

(A) lithium
(B) beryllium
(C) boron
(D) carbon

37 Topaz is a mineral with the formula $Al_2SiO_4(OH)_2$. What is the percentage by mass of aluminium in topaz?

(A) 15%
(B) 16%
(C) 30%
(D) 45%

38 A boy was investigating the reactivity of three unknown metals (X, Y and Z) using displacement reactions. He recorded the following balanced chemical equations:

$$X(NO_3)_{2(aq)} + Z_{(s)} \rightarrow X_{(s)} + Z(NO_3)_{2(aq)}$$

$$Z_{(s)} + Y(NO_3)_{2(aq)} \rightarrow Y_{(s)} + Z(NO_3)_{2(aq)}$$

$$Y_{(s)} + X(NO_3)_{2(aq)} \rightarrow \text{no visible reaction}$$

Which of the following correctly places the three metals in order of **increasing** reactivity?

(A) Y, X, Z
(B) Z, Y, X
(C) X, Z, Y
(D) Z, X, Y

39 Which of the following best describes the molecular shape of methane?

(A) trigonal planar
(B) bent
(C) trigonal pyramidal
(D) tetrahedral

40 In which of the following substances would you expect hydrogen bonding to occur?

I. CH_2F_2
II. CH_3COOH
III. C_2H_5OH

(A) II only
(B) I and III only
(C) II and III only
(D) I, II and III

41 The specific heat capacity of gold is 0.128 J g^{-1} K^{-1}, and the specific heat capacity of copper is 0.385 J g^{-1} K^{-1}. Ten gram samples of each metal were heated to 60 °C, and then dropped into separate beakers containing 20 mL of water.

Which of the following statements are correct?

(A) The copper will react with the water, but the gold will not.
(B) The copper sample will transfer more heat energy to the water than the gold sample.
(C) The water with the gold sample will have has a final temperature three times higher than the water with the copper sample.
(D) The water in the two beakers will remain at the same temperature at all times.

42 When aqueous solutions of hydrochloric acid and sodium hydroxide are mixed, the temperature of the resulting solution increases. Therefore, the reaction

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

(A) is endothermic with $\Delta H^o > 0$
(B) is endothermic with $\Delta H^o < 0$
(C) is exothermic with $\Delta H^o < 0$
(D) is exothermic with $\Delta H^o > 0$

43 Which one of the following processes is endothermic?

(A) Combustion of natural gas.
(B) Freezing of water to make ice.
(C) Photosynthesis.
(D) Dilute acid reacting with an active metal.

44 Which of the following contains only molecules with dipole-dipole interactions as their main intermolecular force?

(A) Hydrogen chloride, hydrogen sulfide, water.
(B) Ammonia, phosphorus trifluoride, carbon dioxide.
(C) Ammonia, sodium chloride, methane.
(D) Hydrogen chloride, hydrogen sulfide, phosphorus trifluoride.

45 The density of water at 4°C is 1.00 $g.mL^{-1}$. The density of ice at 0 °C is 0.917 $g\ mL^{-1}$. What volume change would occur if an ice cube of mass 7.40 g, initially at 0 °C, melted to form liquid water with a final temperature of 4 °C?

(A) The volume would increase by 0.61 mL.
(B) The volume would decrease by 0.61 mL.
(C) The volume would increase by 0.67 mL.
(D) The volume would decrease by 0.67 mL.

46 Within a Group of the Periodic Table, which is the correct relationship between a property of a metal and the first ionization energy of the metal?

(A) The larger the atom, the smaller the ionisation energy.
(B) The greater the reactivity of the metal, the greater the ionisation energy.
(C) The smaller the amount of energy required to remove an electron from the metal, the greater the ionisation energy.
(D) The more difficult it is for a metal to lose an electron, the smaller the ionisation energy.

47 What is the relationship between the potential energy of an electron and its average distance from the nucleus?

(A) The energy of an electron is variable, irrespective of its location.
(B) By definition, all electrons have the same amount of energy, irrespective of their location.
(C) The greater the average distance of the electron from the nucleus the less its potential energy.
(D) The greater the average distance of the electron from the nucleus the greater its potential energy.

48 Identify which row below contains the correct information about the boiling and electrolysis of water.

	Type of separation	**Amount of energy required**	**Result of Process**
(A)	Boiling	Relatively large amount of energy	New chemical substance formed
(B)	Boiling	Relatively small amount of energy	No new chemical substance formed
(C)	Electrolysis	Relatively small amount of energy	New chemical substance formed
(D)	Electrolysis	Relatively large amount of energy	No new chemical substance formed

49 Which of the following statements about empirical formulae is correct?

(A) They express the simplest ratio of protons to neutrons present in a compound.
(B) They provide information about the elements present in a compound but don't provide information about the number of particles.
(C) They can only be applied to ionic compounds.
(D) They show the number of atoms of different elements in a molecule.

Master's initials

Name

Answer the questions in the spaces provided.
Show **all** relevant working in questions involving calculations.

Question 50 (2 marks) **Marks**

In the spaces provided below draw Lewis electron dot structures for the following compounds.

Methane

1

Carbon dioxide

1

Question 51 (3 marks) **Marks**

1.00 g of solid FeS is reacted in excess hydrochloric acid according to the equation below.

$FeS_{(s)} + 2\ HCl_{(aq)} \rightarrow FeCl_{2\ (aq)} + H_2S_{(g)}$

Determine if each statement below is correct and place a tick by those that are correct and a cross next to those that are incorrect.

__ The systematic name of FeS is iron(III) sulfide.

__ The chloride ion is a spectator ion in this reaction.

__ One half equation for this reaction can be written $2\ H^+ + 2\ e^- \rightarrow H_{2(g)}$

__ H_2S is a polar molecule.

__ $FeCl_2$ is a polar molecule.

__ H_2S is linear in shape.

__ H_2S has one lone pair of electrons on the sulfur.

__ The molar mass of FeS is 87.92 g mol^{-1}.

__ 0.0114 moles of HCl react.

3

Question 52 (2 marks) **Marks**

Write the following reactions as balanced chemical equations including states

(i) The decomposition of copper(II) carbonate.

_____ **1**

(ii) Addition of lithium to a large beaker of water.

_____ **1**

Question 53 (6 marks) **Marks**

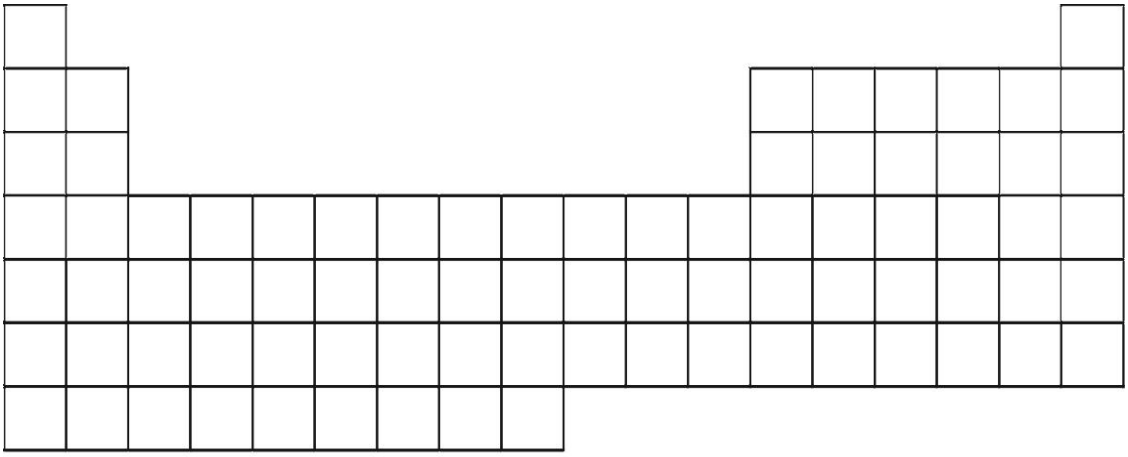
(a) Describe the bonding and structure that occurs in metals and discuss how this leads to their unique properties of ductility and conductivity. **3**

(b) Covalent compounds can be either molecular or covalent network in structure. Explain, in terms of their structure and bonding, why they have vastly different melting points. **3**

Question 54 (2 marks) **Marks**

Place each of the elements **A – D** (not their chemical symbols) in the blank Periodic Table below. The electron configurations of **atoms** *or* **ions** of the elements are as follows:

A: 2.5
B: 2.8.1
C^{2+}**:** 2.8
D^{3-}**:** 2.8.8



2

Question 55 (3 marks) **Marks**

Write net ionic and half equations for the reaction of magnesium with sulfuric acid.

Net ionic equation: **1**

Oxidation half equation: **1**

Reduction half equation: **1**

Master's initials

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Question 56 (4 marks) **Marks**

Eight consecutive elements of the first 20 elements on the periodic table have the following first ionization energies.

Element	A	B	C	D	E	F	G	H	I
First ionisation energy	1.407	1.320	1.687	2.087	0.502	0.744	0.584	0.793	

(a) Which element will have the highest second ionization energy? **1**

(b) Estimate the first ionization energy for the 9^{th} consecutive element "I". **1**

(c) Identify two elements that will react to form a covalent molecular compound. **1**

(d) Identify the **formulae** of ionic compounds that would form using the above elements. **1**

Formula 1:

Formula 2:

Question 57 (3 marks) **Marks**

A sample of vanadium metal is placed in a crucible and heated until it has completely converted to an oxide. Masses of the crucible and samples were recorded in the table below. Determine the empirical formula of the oxide.

Item	Mass (g)
Crucible	2.500
Crucible and metal	3.000
Crucible and metal oxide	3.236

3

Question 58 (4 mark) **Marks**

Hydrogen gas is formed when aluminium foil reacts with sodium hydroxide solution according to the equation.

$$2Al_{(s)} + 2NaOH_{(aq)} + 6H_2O_{(l)} \longrightarrow 2NaAl(OH)_{4(aq)} + 3H_{2(g)}$$

Calculate the volume of hydrogen produced at 0 °C and 100 kPa when 2.00 g of aluminium is placed in a 20 mL of aqueous solution containing 2.00 g of sodium hydroxide.

4

Master's initials

Name

Question 59 (4 marks) **Marks**

(a) If the theoretical value for the heat of solution of potassium nitrate is +34.89 kJ/mol, use this to calculate the mass of potassium nitrate that would be required to decrease the temperature of 100 mL of the water solvent by 2.7 °C.

3

(b) When the boys performed this experiment for themselves, they were surprised to find that the value they obtained for the heat of solution of potassium nitrate was around half the theoretical value. Identify the most likely reason for this discrepancy.

1

Question 60 (2 mark)

Calculate the mass of an atom of sulfur.

2

Master's initials

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Question 61 (6 marks) **Marks**

(a) Write balanced chemical equations for the following reactions:

i. Decomposition of silver chloride.

_____ **2**

ii. Reaction of aqueous solutions of barium nitrate and copper(II) sulfate.

_____ **2**

(b) Write a balanced net ionic equation for the following reaction:

i. Reaction of aqueous solutions of lead(II) nitrate and potassium iodide.

_____ **2**

Question 62 (5 marks) **Marks**

During the course of this year you have performed a first-hand investigation to separate a naturally occurring mixture of sand, salt and water.

(a) Identify the separation technique you used to perform the separation of the sand from salt water and state the physical property which enabled this technique.

2

(b) One of your classmates was given a sample of this mixture and asked to perform a gravimetric analysis of it. He found that at 22 °C the sample contained 0.573 L of water (density at 22 °C is 0.9978 g mL^{-1}), 7.8 g of sand and 2.6 g of salt.

Determine the percentage composition by mass of **water** in this sample.

3

Question 63 (3 marks) **Marks**

Consider the representation of an atom shown below.

Using the letters in the representation above, identify:

(a) The number of protons in this atom.

_____ **1**

(b) The number of neutrons in this atom.

_____ **1**

(c) An expression for the number of electrons found in an ion of this element if the element belongs to group 5 of the periodic table.

_____ **1**

Question 64 (3 marks) **Marks**

Identify the property or substance represented by the letters X, Y and Z in the table below.

Group	Metals	Metalloids	Non-metals
Appearance	lustrous	Low-sheen	dull
Electrical Conductivity	High	low	Y
Thermal Conductivity	high	high	low
Malleability	X	moderate	low
Density	high	intermediate	low
Boiling point	high	high	low
Tensile strength	High	variable	low
Examples	Zinc	Z	Argon

X : _____ **1**

Y : _____ **1**

Z : _____ **1**

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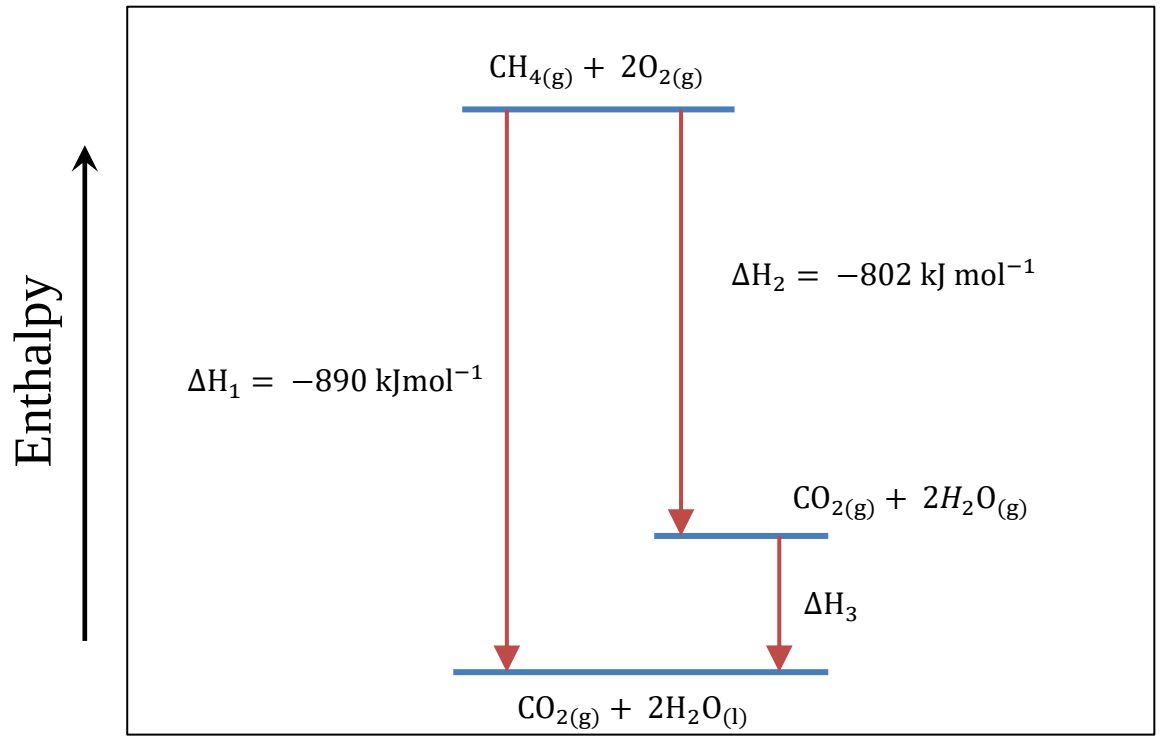
Question 65 (5 marks) **Marks**

Both ionic compounds and metallic elements are most commonly found as lattice structures. Compare these two types of lattice structures in terms of their structure and bonding.

5

Question 66 (2 marks) **Marks**

Hess's Law states that the total enthalpy change during the complete course of a chemical reaction is the same irrespective of the pathway taken i.e. whether the reaction is made in one step or in several steps. Consider the following example for the complete combustion of methane.



If Hess's Law holds for the above example, calculate ΔH_3.

2

Master's initials

Name

Question 67 (3 marks) **Marks**

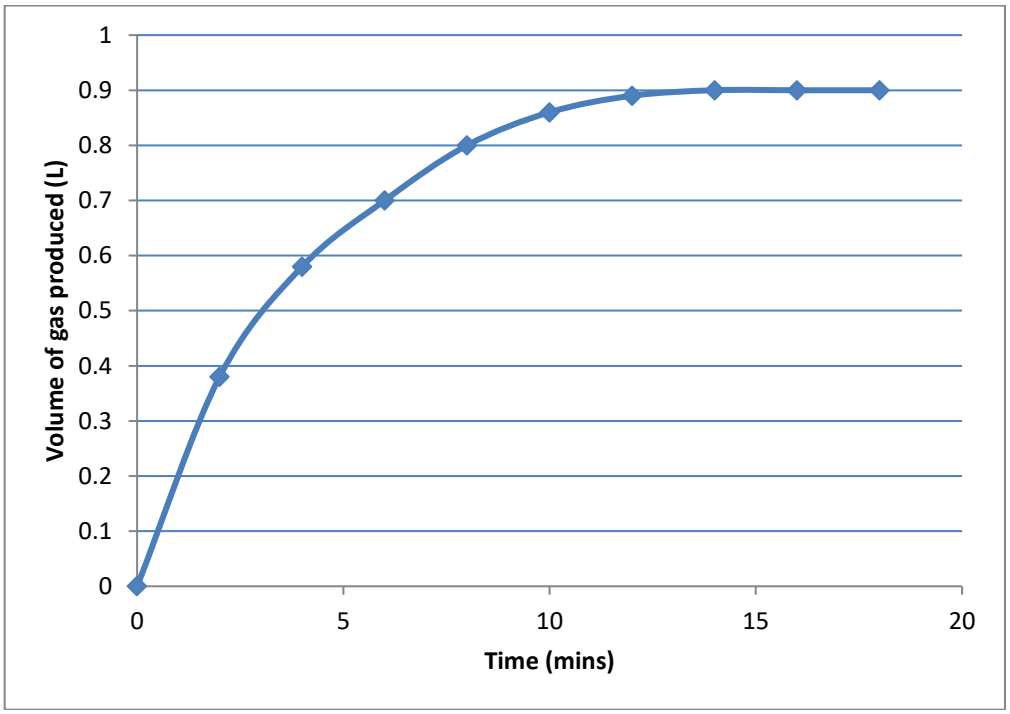
With reference to the tabulated first ionisation energies below, explain the differences in reactivity between potassium and rubidium.

Metal	First Ionisation Energy ($kJ\ mol^{-1}$)
Potassium	425
Rubidium	403

3

Question 68 (6 marks) **Marks**

Excess copper(II) carbonate was placed in a conical flask and 100.0 mL of dilute sulfuric acid was added. A reaction occurred and the gas produced was collected. The volume of gas collected at 100 kPa and 25 °C is shown in the graph below.



Calculate the concentration of the sulfuric acid.

3

Question 69 (7 marks)

Solutions of $FeCl_{2(aq)}$ oxidise easily in the presence of oxygen to produce $FeCl_{3(aq)}$. Iron filings can be added to stabilise these solutions by reducing any $FeCl_{3(aq)}$ formed back to $FeCl_{2(aq)}$ according to the following equation.

$$Fe_{(s)} + 2FeCl_{3(aq)} \longrightarrow 3FeCl_{2(aq)}$$

(a) Write the net ionic equation for this reaction.

1

(b) Write the reduction and oxidation half equations for these reactions.

(i) Reduction

1

(ii) Oxidation

1

(c) Calculate the mass of $FeCl_3$ can be reduced completely to $FeCl_2$ by 1.00 g of $Fe_{(s)}$.

4

Question 70 (4 marks) **Marks**

2.67 L of vapourised phosphorus molecules are reacted with 8.01 L of oxygen gas at a constant temperature and pressure to produce 2.67 L of a gaseous oxide of phosphorus having a molar mass of 220 g mol^{-1}.

(a) Balance the given equation below for the reaction.

$$P_{x(g)} + O_{2(g)} \rightarrow P_xO_{y(g)}$$ **1**

(b) Determine the formula of the oxide of phosphorus. Show working.

2

(c) Determine the molecular formula of the vapourised phosphorus molecules.

1

Question 71 (6 marks) **Marks**

(a) Construct Lewis dot diagrams of the following molecules

(i) methane

1

(ii) water

1

(iii) hydrogen sulfide (H_2S)

1

(b) Explain why the boiling points of water and hydrogen sulfide differ.

3

Question 72 (5 marks) **Marks**

In an experiment, a boy added 8.00 g of ammonium nitrate to 100 g of water.

(a) If the $\Delta_{sol}H$ for ammonium nitrate is +25.41 kJ mol^{-1} and the water was initially 25.0 °C, calculate the final temperature of the resulting solution.

3

(b) The boy actually measured a final temperature of 22.1 °C. Suggest two possible reasons as to why there is a difference between these results.

2

Question 73 (3 marks) **Marks**

Write balanced chemical equations for the following reactions, including states:

(a) Magnesium oxide with hydrochloric acid.

_____ **1**

(b) Sodium hydrogen carbonate with sulfuric acid.

_____ **1**

(c) Sodium with water.

_____ **1**

Question 74 (3 marks)

Pentane and water are immiscible liquids that have the properties below.

	Boiling Point (^oC)	**Density ($g\ cm^{-3}$)**
Pentane	36	0.6
Water	100	1.0

Assess the relative suitability of distillation or a separating funnel as techniques to separate pentane and water. **3**

_____

_____

_____

_____

_____

_____

_____

_____

Marks

Question 75 (3 marks)

Complete the following table.

Name of Element or Ion	Protons	Charge	Electron Configuration
	12		2.8
Phosphorus		0	
		$^{-}1$	2.8.8

3

Question 76 (4 marks)

Draw Lewis electron dot diagrams for the following materials.

H_2	O_2
H_2O	OH^-

4

Question 77 (3 marks) **Marks**

A sample of processed meat was placed in a container of known mass and dried in an oven until the mass no longer reduced. The various masses were recorded in the table below.

Item	Mass (g)
Container	21.3
Container and undried meat sample	24.2
Container and dried meat sample	23.4

Determine the percentage water by mass in the original sample of processed meat.

3

Question 78 (3 marks)

(a) Write a balanced equation for the reaction of aluminium with sulfuric acid.

1

(b) Write and identify the reduction and oxidation half equations for the reaction of aluminium with sulfuric acid.

Reduction: _____ **2**

Oxidation: _____

Question 79 (4 marks) **Marks**

Potassium is ductile while potassium chloride is brittle. Explain the difference in these properties in terms of the structure and bonding of the two materials.

4

Question 80 (2 marks)

A pupil was given three metal samples (lead, silver and magnesium), but they forgot to label the samples. The pupil then conducted the following tests.

Metal	**Reaction with H_2O**	**Reaction with acid**	**Reaction with oxygen**
1	No Visible Reaction	No Visible Reaction	No Visible Reaction
2	White coating formed in near-boiling water	Reacted vigorously with cold H_2SO_4	Burned readily as a thin foil
3	No Visible Reaction	Reacted slowly with warm H_2SO_4	Formed a red/brown layer when heated in air

Identify the metals 1, 2 and 3.

Metal 1: _____ **2**

Metal 2: _____

Metal 3: _____

Question 81 (6 marks) **Marks**

Five **consecutive** elements in increasing atomic number have **first** ionisation energies as shown in the table below.

Element	W	V	X	Y	Z
First ionisation energy (kJ / mol)	1260	1520	418	590	632

(a) Define First Ionisation Energy

_____ **1**

_____

(b) Identify which element/(s) (W-Z) would be most likely to:

(i) be a noble gas.

_____ **1**

(ii) form an ion with a 1+ charge.

_____ **1**

(iii) be metals.

_____ **1**

(iv) exist as a diatomic molecule.

_____ **1**

(v) react most vigorously with dilute hydrochloric acid.

_____ **1**

Question 82 (4 marks) **Marks**

Explain why atomic radii decrease as you move along a Period of the Periodic Table but increase as you move down a Group.

4

Question 83 (3 marks)

Complete the table below by using the physical properties in the table to classify the following elements as metals, non-metals or semi-metals and solids, liquids or gases.

	Melting Point (ºC)	**Boiling Point (ºC)**	**Density (g cm^{-3})**	**Electrical conductivity (MS m^{-1})**	**Metal/Non-metal/Semi-metal**	**Solid/Liquid/ Gas at 300ºC**
A	63	760	0.86	14		
B	44	280	1.82	10^{-15}		
C	-39	357	13.5	1.0		
D	937	2830	5.3	10^{-4}		

3

Question 84 (7 marks) **Marks**

Chromium is often found in the Earth's crust as chromite, $FeCr_2O_4$. The production of chromium metal from chromite involves a series of chemical reactions:

$4\ FeCr_2O_{4(s)} + 8\ Na_2CO_{3(s)} + 7\ O_{2(g)} \rightarrow 8\ Na_2CrO_{4(s)} + 2\ Fe_2O_{3(s)} + 8\ CO_{2(g)}$

$2\ Na_2CrO_{4(s)} + H_2SO_{4(aq)} \rightarrow Na_2Cr_2O_{7(s)} + Na_2SO_{4(aq)} + H_2O_{(l)}$

$Na_2Cr_2O_{7(s)} + 2\ C_{(s)} \rightarrow Cr_2O_{3(s)} + Na_2CO_{3(s)} + CO_{(g)}$

$Cr_2O_{3(s)} + 2\ Al_{(s)} \rightarrow Al_2O_{3(s)} + 2\ Cr_{(s)}$

A 210.0 g ore sample containing 75.40% chromite by mass is processed through this series of chemical reactions.

(a) Calculate the mass of chromite, $FeCr_2O_4$, present in the 210.0 g ore sample. **1**

(b) Calculate the mass of carbon dioxide gas produced when chromium is produced from the 210.0 g ore sample by this process. **3**

Question continued on next page.

Question continued. **Marks**

(c) Calculate the mass of chromium metal produced in this process using the 210.0 g sample.

2

(d) Calculate the number of aluminium atoms consumed in this process.

1

Question 85 (3 marks)

In 1962, the synthesis of the first binary compound of a noble gas was reported in the Journal of the American Chemical Society. Decomposition of this colourless solid compound was reported to give rise to 0.2507 g xenon and 0.1435 g fluorine by mass. Calculate the empirical formula of this compound.

3

Question 86 (5 marks) **Marks**

Argyrodite is a rare mineral that contains only three elements; silver, sulfur and an unknown element **X**. It has a molar mass of between 1000 g mol^{-1} and 1500 $gmol^{-1}$.

The first step to extract silver, sulfur and **X** from the mineral involves roasting the mineral by heating it with oxygen. When 100.0 g of argyrodite is heated with a stoichiometric ratio of 19.77 L of oxygen (measured at 100 kPa and 25 ^{o}C) three binary compounds are obtained; a black solid, a white solid, and 13.18 L of sulfur dioxide gas (measured at 100 kPa and 25 ^{o}C). This black solid can then be heated with carbon monoxide to produce solid silver and 8.789 L of a colourless gas (measured at 100 kPa and 25 ^{o}C).

Use this information to identify element **X** and the empirical formula of argyrodite, showing all working and logic.

5

Question 87 (6 marks) **Marks**

Compound **A** is a white insoluble mineral made of four elements. When 10.000 g of compound **A** is reacted with 2 M HCl, 2.6886 L of CO_2 (measured at 25 °C and 100 kPa), is evolved. Na_2SO_4 is then added to the solution forming 7.383 g of compound **B** as a precipitate; compound **C** remains in solution.

The solution of compound **C** is neutralised with 2 M NaOH forming 3.1628 g of a precipitate of compound **D**, which was filtered. The 3.1628 g of Compound **D** was then heated to produce 2.1859 g of compound **E** and water. Compound **E** was heated at 2300 °C with excess carbon to give CO and 1.3183 g of pure metal **F**.

What are the formulae of compounds **A-F**? Show working.

6

Marks

Question 88 (5 marks)

Wegscheiderite is an evaporite mineral found at the Green River Formation in Wyoming, USA. Elemental analysis shows wegscheiderite to contain four different elements. When 10.000 g of wegscheiderite is treated with excess hydrochloric acid, 4.917 g of carbon dioxide is given off. In a separate experiment, 0.1000 g of wegscheiderite is dissolved in water and treated with excess of a solution of uranyl zinc acetate ($UO_2Zn(CH_3COO)_4$). A precipitate of $(UO_2)_3ZnNa(CH_3COO)_9 \cdot 6H_2O$ (molar mass 1537.9 g mol^{-1}) is produced, which after purification has a mass of 2.148 g.

Calculate the empirical formula of wegscheiderite, showing all working and logic.

5

FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{v} \qquad PV = nRT$$

$$q = mC\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Gas constant ..... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

Compound	K_{sp}
Barium carbonate	2.58×10^{-9}
Barium hydroxide	2.55×10^{-4}
Barium phosphate	1.3×10^{-29}
Barium sulfate	1.08×10^{-10}
Calcium carbonate	3.36×10^{-9}
Calcium hydroxide	5.02×10^{-6}
Calcium phosphate	2.07×10^{-29}
Calcium sulfate	4.93×10^{-5}
Copper(II) carbonate	1.4×10^{-10}
Copper(II) hydroxide	2.2×10^{-20}
Copper(II) phosphate	1.40×10^{-37}
Iron(II) carbonate	3.13×10^{-11}
Iron(II) hydroxide	4.87×10^{-17}
Iron(III) hydroxide	2.79×10^{-39}
Iron(III) phosphate	9.91×10^{-16}

Compound	K_{sp}
Lead(II) bromide	6.60×10^{-6}
Lead(II) chloride	1.70×10^{-5}
Lead(II) iodide	9.8×10^{-9}
Lead(II) carbonate	7.40×10^{-14}
Lead(II) hydroxide	1.43×10^{-15}
Lead(II) phosphate	8.0×10^{-43}
Lead(II) sulfate	2.53×10^{-8}
Magnesium carbonate	6.82×10^{-6}
Magnesium hydroxide	5.61×10^{-12}
Magnesium phosphate	1.04×10^{-24}
Silver bromide	5.35×10^{-13}
Silver chloride	1.77×10^{-10}
Silver carbonate	8.46×10^{-12}
Silver hydroxide	2.0×10^{-8}
Silver iodide	8.52×10^{-17}
Silver phosphate	8.89×10^{-17}
Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.

1 Which separation technique would be best to obtain samples of pure copper sulfate from a solution of copper sulfate?

(A) Evaporation
(B) Centrifugation
(C) Distillation
(D) Filtration

2 Alkali metals become more reactive proceeding down the Group. This is because:

(A) the energy produced in the ionisation of the metal atoms increases.
(B) the energy required to ionise the metal atoms increases.
(C) the energy produced in the ionisation of the metal atoms decreases.
(D) the energy required to ionise the metal atoms decreases.

3 Which of the following statements about bonding between molecules is true?

(A) Only molecules which have H-N, H-O or H-F bonds can produce dipole-dipole bonds.
(B) All molecules which have polar covalent bonds will produce either dipole-dipole or hydrogen bonds.
(C) The larger the molecules in a homologous series the stronger the dispersion forces.
(D) Non-polar molecules have no intermolecular bonds.

4 0.30 moles of magnesium nitrate is weighed out and then dissolved in water to an exact volume of 500 mL. Which of the following is correct?

(A) the concentration of nitrate ions is 0.30 mol L^{-1}
(B) the concentration of magnesium ions is 0.15 mol L^{-1}
(C) the concentration of nitrate ions is 1.2 mol L^{-1}
(D) the concentration of magnesium ions is 0.30 mol L^{-1}

5 Water is considered to have an unusually high specific heat capacity. What does this tell you about water?

(A) Compared to most other materials, a given mass of water will experience a larger temperature change per Joule of energy absorbed or released.
(B) Compared to most other materials, for a given mass of water, a great deal of energy could be absorbed with only a small change in temperature.
(C) Compared to most other materials, for a given body of water, a small amount of energy absorbed will result in a large temperature change.
(D) Compared to most other materials, a large mass of water would be required for a 1K temperature drop to cause a large release of energy.

6 Which of the following is true about endothermic reactions?

(A) They will always have a negative ΔH.
(B) The energy of the reactants will always be greater than that of the products.
(C) There will be a net gain of energy to the chemical system.
(D) Energy will be released in the breaking of bonds and absorbed in the formation of bonds.

7 Which of the following best describes the relationship of graphite and diamond?

(A) They are two isotopes of carbon.
(B) They are two isomers of carbon.
(C) They are two nucleons of carbon.
(D) They are two allotropes of carbon.

8 Which of the following species have the same electron configuration?

(A) F, Cl, Br
(B) Cl^-, Ar, K^+
(C) Na, Mg, Al
(D) Cu, Zn, Fe

9 Which of the following is a correct statement about molecules?

(A) The formula NaCl represents a molecule of sodium chloride.
(B) All covalently bonded substances are made of molecules.
(C) Only compounds can be molecular.
(D) A molecule is a finite structure composed of two or more covalently bonded atoms.

10 The formula for glucose is $C_6H_{12}O_6$. Which of the following is true for $C_6H_{12}O_6$?

(A) It is a molecular formula.
(B) It is a structural formula.
(C) It is an empirical formula.
(D) It is both an empirical and molecular formula.

11 The structure of a metallic lattice can best be described as:

(A) a 3D array of cations held together by a sea of electrons.
(B) a 3D array of alternating cations and anions.
(C) a 3D array of atoms covalently bonded to each other.
(D) a 3D array of dissociated atoms which are free to move around.

12 Which of the following substances has the **largest** molar mass?

(A) lithium sulfate
(B) beryllium sulfate
(C) sodium sulfate
(D) calcium sulfate

13 Which of the following contains the same number of **molecules** as there are **ions** in 1.000 mol of magnesium chloride?

(A) 64.14 g of solid sulfur
(B) 22.71 L of gaseous chlorine (measured at 0 °C and 100 kPa)
(C) 479.4 g of liquid bromine
(D) 49.58 L of gaseous argon (measured at 25 °C and 100 kPa)

14 When sodium reacts with excess oxygen, the major product is sodium peroxide (Na_2O_2). It is formed in accordance with the following balanced chemical equation:

$$2Na(s) + O_2(g) \rightarrow Na_2O_2(s)$$

What mass of sodium peroxide should be produced when 15.00 g of sodium reacts with excess oxygen?

(A) 12.72 g
(B) 25.44 g
(C) 36.55 g
(D) 50.87 g

15 2.000 g of barium chloride is dissolved in water and added to a solution containing excess silver nitrate. What mass of precipitate is formed?

(A) 1.377 g
(B) 1.718 g
(C) 2.510 g
(D) 2.754 g

16 The following table represents successive ionisation energies for Element Y and Element Z. One element is a metal and the other is a non-metal.

Element Y	Element Z
1,012	578
1,903	1,817
2,912	2,745
4,956	11,575
6,273	14,830
22,233	18,376
25,397	23,293

When the two elements were combined under the right conditions a synthesis reaction occurred. Using the data above, determine the correct formula for the resulting compound.

(A) ZY_2
(B) ZY
(C) Y_3Z_5
(D) ZY_3

17 Arrange Na, Al, Rb and Sr metals in order of increasing first ionisation energy:

(A) Na, Al, Rb, Sr
(B) Sr, Rb, Al, Na
(C) Al, Na, Sr, Rb
(D) Rb, Sr, Na, Al

18 Which of the following is true for all metal displacement reactions?

(A) Ions of the less reactive metal gain electrons from the atoms of the more reactive metal.
(B) Ions of the more reactive metal gain electrons from the atoms of the less reactive metal.
(C) Atoms of the more reactive metal gain electrons from the ions of the less reactive metal.
(D) Atoms of the less reactive metal gain electrons from the ions of the more reactive metal.

19 2 L of an unknown gas has the same mass as 0.5 L of bromine gas at the same temperature and pressure. What is the gas?

(A) CO_2
(B) Ne_2
(C) F_2
(D) Ar

20 Moving from left to right across Period 3 of the Periodic Table, which of the following does **not** increase?

(A) The number of electron shells
(B) The total number of electrons
(C) The number of valence electrons
(D) The charge on the nucleus

21 Which of the following elements has the highest electronegativity?

(A) helium
(B) francium
(C) fluorine
(D) nitrogen

22 Which of the following iron-containing minerals has the greatest percentage of iron by mass?

(A) magnetite, $Fe_3O_{4(s)}$
(B) hematite, $Fe_2O_{3(s)}$
(C) siderite, $FeCO_{3(s)}$
(D) goethite, $FeO(OH)_{(s)}$

23 Approximately how many atoms are there in 1.00 g of water?

(A) 3.34×10^{22}
(B) 1.00×10^{23}
(C) 6.02×10^{23}
(D) 1.81×10^{24}

24 Which of the following substances has the **smallest** molar mass?

(A) sodium oxide
(B) magnesium oxide
(C) potassium oxide
(D) calcium oxide

25 When comparing a more reactive metal with a less reactive metal:

(A) The less reactive metal is more likely to be found as an uncombined naturally occurring element.
(B) The more reactive metal is more spontaneous in losing electrons than is the less reactive metal.
(C) More energy is required to extract the less reactive metal from one of its compounds.
(D) More reactive metals absorb more heat than less reactive metals when they react.

26 Nitrogen trifluoride can be decomposed to form nitrogen and fluorine gas. Which of the following balanced equations correctly represents this reaction?

(A) $NF_{3(g)} \rightarrow N_{(g)} + F_{3(g)}$
(B) $2N_3F_{3(g)} \rightarrow 3N_2F_{2(g)}$
(C) $2NF_{3(g)} \rightarrow N_{2(g)} + 3F_{2(g)}$
(D) $NF_{3(g)} \rightarrow N_{(g)} + 3F_{(g)}$

27 Which of the following shows elements in increasing atomic mass?

(A) Cl, Ar, K, Ca,
(B) Zn, Cu, Ni, Co
(C) Cs, Rb, K, Na
(D) I, Te, Xe, Cs

28 In which of the following substances do strong chemical bonds **NOT** extend throughout the crystal lattice in the **solid** state?

(A) mercury
(B) iodine
(C) silicon dioxide
(D) sodium chloride

29 Using the solubility rules, determine which of the following combinations of solutions would form a precipitate.

(A) Magnesium sulfate and barium nitrate
(B) Barium chloride and sodium hydroxide
(C) Sodium carbonate and lithium nitrate
(D) Silver nitrate and potassium nitrate

30 Which of the following contains the same number of ions as 1 mole of aluminium chloride?

(A) 3 mole of sodium hydroxide
(B) 2 mole of barium carbonate
(C) 1 mole of ammonium nitrate
(D) 0.5 mole of ammonium sulfate

31 Consider the following atom, $^{17}_{8}O$. This atom contains:

(A) 8 protons, 8 electrons and 17 neutrons.
(B) 8 protons, 8 electrons and 9 neutrons.
(C) 9 protons, 9 electrons and 17 neutrons.
(D) 17 protons, 17 electrons and 8 neutrons.

32 Which of the following is the name for FeS?

(A) iron monosulfide
(B) iron monosulfate
(C) iron(II) sulfide
(D) iron(II) sulfate

33 Which of the following methods would best enable you to separate two immiscible liquids?

(A) using a separating funnel
(B) using a filter funnel
(C) using evaporation
(D) using distillation

34 Which compound contains both covalent and ionic bonds?

(A) $MgBr_2$
(B) $CHCl_3$
(C) BCl_3
(D) NH_4NO_3

35 An atom of element Z (not correct symbol) has the electronic configuration 2, 8, 6. Which of the following species is this element most likely to form?

(A) the ion Z^{2+}
(B) the ion Z^{6+}
(C) the compound H_2Z
(D) the compound Z_6F

36 The first four successive ionisation energies (measured in kJ mol^{-1}) for an element are 550, 1064, 4210 and 5500. This element should be placed in the same group as:

(A) lithium
(B) beryllium
(C) boron
(D) carbon

37 Topaz is a mineral with the formula $Al_2SiO_4(OH)_2$. What is the percentage by mass of aluminium in topaz?

(A) 15%
(B) 16%
(C) 30%
(D) 45%

38 A boy was investigating the reactivity of three unknown metals (X, Y and Z) using displacement reactions. He recorded the following balanced chemical equations:

$$X(NO_3)_{2(aq)} + Z_{(s)} \rightarrow X_{(s)} + Z(NO_3)_{2(aq)}$$

$$Z_{(s)} + Y(NO_3)_{2(aq)} \rightarrow Y_{(s)} + Z(NO_3)_{2(aq)}$$

$$Y_{(s)} + X(NO_3)_{2(aq)} \rightarrow \text{no visible reaction}$$

Which of the following correctly places the three metals in order of **increasing** reactivity?

(A) Y, X, Z
(B) Z, Y, X
(C) X, Z, Y
(D) Z, X, Y

39 Which of the following best describes the molecular shape of methane?

(A) trigonal planar
(B) bent
(C) trigonal pyramidal
(D) tetrahedral

40 In which of the following substances would you expect hydrogen bonding to occur?

I. CH_2F_2
II. CH_3COOH
III. C_2H_5OH

(A) II only
(B) I and III only
(C) II and III only
(D) I, II and III

41 The specific heat capacity of gold is 0.128 J g^{-1} K^{-1}, and the specific heat capacity of copper is 0.385 J g^{-1} K^{-1}. Ten gram samples of each metal were heated to 60 °C, and then dropped into separate beakers containing 20 mL of water.

Which of the following statements are correct?

(A) The copper will react with the water, but the gold will not.
(B) The copper sample will transfer more heat energy to the water than the gold sample.
(C) The water with the gold sample will have has a final temperature three times higher than the water with the copper sample.
(D) The water in the two beakers will remain at the same temperature at all times.

42 When aqueous solutions of hydrochloric acid and sodium hydroxide are mixed, the temperature of the resulting solution increases. Therefore, the reaction

$$H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(l)}$$

(A) is endothermic with $\Delta H^o > 0$
(B) is endothermic with $\Delta H^o < 0$
(C) is exothermic with $\Delta H^o < 0$
(D) is exothermic with $\Delta H^o > 0$

43 Which one of the following processes is endothermic?

(A) Combustion of natural gas.
(B) Freezing of water to make ice.
(C) Photosynthesis.
(D) Dilute acid reacting with an active metal.

44 Which of the following contains only molecules with dipole-dipole interactions as their main intermolecular force?

(A) Hydrogen chloride, hydrogen sulfide, water.
(B) Ammonia, phosphorus trifluoride, carbon dioxide.
(C) Ammonia, sodium chloride, methane.
(D) Hydrogen chloride, hydrogen sulfide, phosphorus trifluoride.

45 The density of water at 4°C is 1.00 $g.mL^{-1}$. The density of ice at 0 °C is 0.917 $g\ mL^{-1}$. What volume change would occur if an ice cube of mass 7.40 g, initially at 0 °C, melted to form liquid water with a final temperature of 4 °C?

(A) The volume would increase by 0.61 mL.
(B) The volume would decrease by 0.61 mL.
(C) The volume would increase by 0.67 mL.
(D) The volume would decrease by 0.67 mL.

46 Within a Group of the Periodic Table, which is the correct relationship between a property of a metal and the first ionization energy of the metal?

(A) The larger the atom, the smaller the ionisation energy.
(B) The greater the reactivity of the metal, the greater the ionisation energy.
(C) The smaller the amount of energy required to remove an electron from the metal, the greater the ionisation energy.
(D) The more difficult it is for a metal to lose an electron, the smaller the ionisation energy.

47 What is the relationship between the potential energy of an electron and its average distance from the nucleus?

(A) The energy of an electron is variable, irrespective of its location.
(B) By definition, all electrons have the same amount of energy, irrespective of their location.
(C) The greater the average distance of the electron from the nucleus the less its potential energy.
(D) The greater the average distance of the electron from the nucleus the greater its potential energy.

48 Identify which row below contains the correct information about the boiling and electrolysis of water.

	Type of separation	**Amount of energy required**	**Result of Process**
(A)	Boiling	Relatively large amount of energy	New chemical substance formed
(B)	Boiling	Relatively small amount of energy	No new chemical substance formed
(C)	Electrolysis	Relatively small amount of energy	New chemical substance formed
(D)	Electrolysis	Relatively large amount of energy	No new chemical substance formed

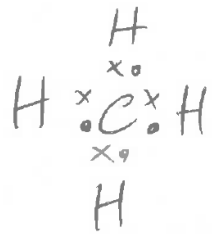
49 Which of the following statements about empirical formulae is correct?

(A) They express the simplest ratio of protons to neutrons present in a compound.
(B) They provide information about the elements present in a compound but don't provide information about the number of particles.
(C) They can only be applied to ionic compounds.
(D) They show the number of atoms of different elements in a molecule.

Q50

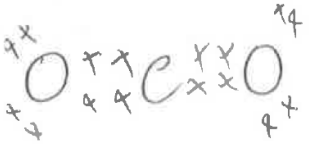
In the spaces provided below draw Lewis electron dot structures for the following compounds.

Methane



* some boys draw ammonia — not methane. **1**

Carbon dioxide



1

* Some boys forgot lone pairs on 2x O.

Q51

1.00 g of solid FeS is reacted in excess hydrochloric acid according to the equation below.

$FeS_{(s)} + 2\ HCl_{(aq)} \rightarrow FeCl_{2\ (aq)} + H_2S_{(g)}$

Determine if each statement below is correct and place a tick by those that are correct and a cross next to those that are incorrect.

X The systematic name of FeS is iron(III) sulfide.

✓ The chloride ion is a spectator ion in this reaction.

X One half equation for this reaction can be written $2\ H^+ + 2\ e^- \rightarrow H_{2(g)}$ → H_2S not H_2

✓ H_2S is a polar molecule.

X $FeCl_2$ is a polar molecule. ionic! (especially when (aq).

X H_2S is linear in shape. bent - same as water

X H_2S has one lone pair of electrons on the sulfur. 2 pairs

✓ The molar mass of FeS is 87.92 g mol^{-1}.

X 0.0114 moles of HCl react.

3 marks - 9 correct.
2 marks - 6 - 8 correct.
1 mark - 2 - 5 correct
0 < 2.

3

* Most common errors are annotated in list above

Q52

Write the following reactions as balanced chemical equations including states

(i) The decomposition of copper carbonate.

$CuCO_{3(s)} \longrightarrow CuO_{(s)} + CO_{2(g)}$ 1

(ii) Addition of lithium to a large beaker of water.

$2Li_{(s)} + 2H_2O_{(l)} \longrightarrow 2LiOH_{(aq)} + H_{2(g)}$ 1

Q53

(a) Describe the bonding and structure that occurs in metals and discuss how this leads to their unique properties of ductility and conductivity. 3

(1) 3D lattice of cations in a "sea" of delocalised electrons

(1) Electrons are able to move and therefore carry charge

(1) The electrons are able to move to balance charges as the cations are shifted when drawn into wires

(b) Covalent compounds can be either molecular or covalent network in structure. Explain, in terms of their structure and bonding, why they have vastly different melting points. 3

Must talk about structure and bonding, many mistook bonding for molecular attractions

(1) Covalent molecules are finite structures held together with covalent bonds but there are weak attractions between molecules

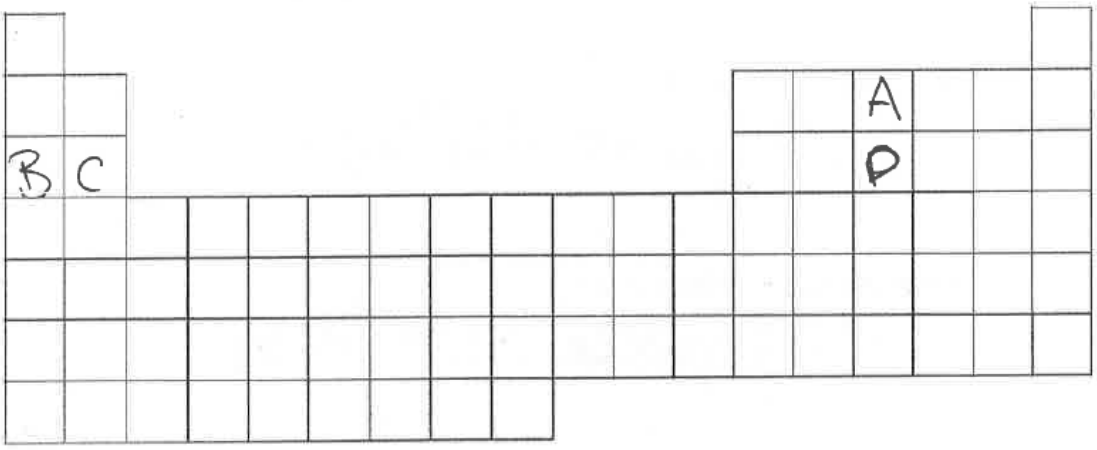
(1) Covalent Network large 3D lattice held together by ~~covalent~~ covalent bonds

(1) Covalent bonds require more energy to break than weak attractions between molecules ∴ have a higher Melting point.

Q54

Place each of the elements **A – D** (not their chemical symbols) in the blank Periodic Table below. The electron configurations of **atoms** *or* **ions** of the elements are as follows:

A: 2.5
B: 2.8.1
C^{2+}: 2.8
D^{3-}: 2.8.8



2

Q55

Net ionic equation: 1

$Mg_{(s)} + 2H^+_{(aq)} \longrightarrow Mg^{2+}_{(aq)} + H_{2(g)}$

Oxidation half equation: 1

$Mg_{(s)} \longrightarrow Mg^{2+}_{(aq)} + 2e^-$

Reduction half equation: 1

$2H^+_{(aq)} + 2e^- \longrightarrow H_{2(g)}$

note: . if oxidation and reduction swapped 1/2
. Carry through error given if used same H species in net ionic and in Reduction equation.

Q56

Eight consecutive elements of the first 20 elements on the periodic table have the following first ionization energies.

Element	A	B	C	D	E	F	G	H	I
First ionisation energy	1.407	1.320	1.687	2.087	0.502	0.744	0.584	0.793	

(a) Which element will have the highest second ionization energy. **1**

E

(b) Estimate the first ionization energy for the 9th consecutive element "I". **1**

0.793 → 1.407 (not inclusive)

(c) Identify two elements that will react to form a covalent molecular compound. **1**

A, B, C, H not D (inert).

(d) Identify the **formulae** of ionic compounds that would form using the above elements. **1**

Formula 1: Correct combinations of

Formula 2: EFG with ABC not D

Q57

A sample of vanadium metal is placed in a crucible and heated until it has completely converted to an oxide. Masses of the crucible and samples were recorded in the table below. Determine the empirical formula of the oxide.

Item	Mass (g)
Crucible	2.500
Crucible and metal	3.000
Crucible and metal oxide	3.236

1 Mark. $m_V = 6.50g$ $m_O = 0.236g$. 3

1 Mark $n_V = 0.00982$ $n_O = 0.01475$

1 Mark correct formula including symbols

V_2O_3.

Q58

Hydrogen gas is formed when aluminium foil reacts with sodium hydroxide solution according to the equation.

$$2Al_{(s)} + 2NaOH_{(aq)} + 6H_2O_{(l)} \longrightarrow 2NaAl(OH)_{4(aq)} + 3H_{2(g)}$$

Calculate the volume of hydrogen produced at 0 °C and 100 kPa when 2.00 g of aluminium is placed in a 20 mL of aqueous solution containing 2.00 g of sodium hydroxide.

4

1 Mark $n_{Al} = \frac{2}{26.98} = 0.0743$ mol.

$n_{NaOH} = \frac{2}{40.01} = 0.0500$ mol.

1 Mark NaOH is rate limiting

1 Mark Ratio NaOH to H_2 is 2:3

1 Mark $V_{H_2} = \frac{3}{2} \times 0.0500 \times 22.71$

$= 1.70\,L$ (3 sf).

Q59

(a) If the theoretical value for the heat of solution of potassium nitrate is +34.89 kJ/mol, use this to calculate the mass of potassium nitrate that would be required to decrease the temperature of 100 mL of the water solvent by 2.7 °C.

$\Delta H = \frac{-mc\Delta T}{n} \therefore n = \frac{-mc\Delta T}{\Delta H} = \frac{-100 \times 4.18 \times -2.7}{34890}$ (1) 3

Molar mass $KNO_3 = 101.11$ $= \frac{1128.6}{34890} = 0.03235$ mol (1)

Mass of $KNO_3 = 101.11 \times 0.03235 = 3.27$ g (1)

(b) When the boys performed this experiment for themselves, they were surprised to find that the value they obtained for the heat of solution of potassium nitrate was around half the theoretical value. Identify the most likely reason for this discrepancy.

Heat gain from the unmonitored environment (1)

or not all KNO_3 dissolved.

(Did not accept "impurities")

Q60

Calculate the mass of an atom of sulfur.

$\frac{32.07}{6.022 \times 10^{23}} = 5.325 \times 10^{-23}$ g (1) 2

unit + sig figs for correct answer (1)

Q61

(a) Write balanced chemical equations for the following reactions:

i. Decomposition of silver chloride.

$2AgCl_{(s)} \rightarrow 2Ag_{(s)} + Cl_{2(g)}$ ← 2

minus 1 for each mistake

ii. Reaction of aqueous solutions of barium nitrate and copper(II) sulfate.

$Ba(NO_3)_{2(aq)} + CuSO_{4(aq)} \rightarrow Cu(NO_3)_{2(aq)} + BaSO_{4(s)}$ ↓ 2

(b) Write a balanced net ionic equation for the following reaction:

i. Reaction of aqueous solutions of lead(II) nitrate and potassium iodide.

$Pb^{2+}_{(aq)} + 2I^-_{(aq)} \rightarrow PbI_{2(s)}$ 2

MINUS 1 FOR EACH MISTAKE

Many boys had several bites at the cherry, writing the equation in different forms. Boys were penalised for each mistake they made, although not for writing several equations. This will not necessarily be the case in future exams (ie HSC).

Q62

During the course of this year you have performed a first-hand investigation to separate a naturally occurring mixture of sand, salt and water.

(a) Identify the separation technique you used to perform the separation of the sand from salt water and state the physical property which enabled this technique.

Filtration 1 MARK

Particle Size / Solubility 1 MARK

2

(b) One of your classmates was given a sample of this mixture and asked to perform a gravimetric analysis of it. He found that at 22 °C the sample contained 0.573 L of water (density at 22 °C is 0.9978 g mL^{-1}), 7.8 g of sand and 2.6 g of salt.

Determine the percentage composition by mass of **water** in this sample.

Mass of water = $0.9978 \times 0.573 \times 10^{+3}$

$= 5.7174 \times 10^{2}$ g 1 MARK

Total mass = $5.7174 \times 10^{2} + 7.8 + 2.6$ 1 MARK

$= 582.14$ g

$\%\ comp = \frac{571.74}{582.14} \times 100 = 98.2\%$ 1 MARK

3

Q63

Consider the representation of an atom shown below.

Using the letters in the representation above, identify:

(a) The number of protons in this atom.

Z

1

(b) The number of neutrons in this atom.

A − Z

1

(c) An expression for the number of ~~valence~~ electrons found in an ion of this element if the element belongs to group 5 of the periodic table.

Z + 3

1

Valence electrons 8, 18, 32....

Q64

Identify the property or substance represented by the letters X, Y and Z in the table below.

Group	Metals	Metalloids	Non-metals
Appearance	lustrous	Low-sheen	dull
Electrical Conductivity	High	low	Y
Thermal Conductivity	high	high	low
Malleability	X	moderate	low
Density	high	intermediate	low
Boiling point	high	high	low
Tensile strength	High	variable	low
Examples	Zinc	Z	Argon

X : High/good _____ 1

Y : ~~Any~~ Low/poor _____ 1

Z : ~~Low/poor~~ any _____ 1

Q65

Both ionic compounds and metallic elements are most commonly found as lattice structures. Compare these two types of lattice structures in terms of their structure and bonding.

Marked holistically.
5 marks required detailed discussion of S&B of both metals and ionic compounds, plus gives a direct comparison between them. Following codes for used to indicate what was missing or insufficiently covered (-1 per item):

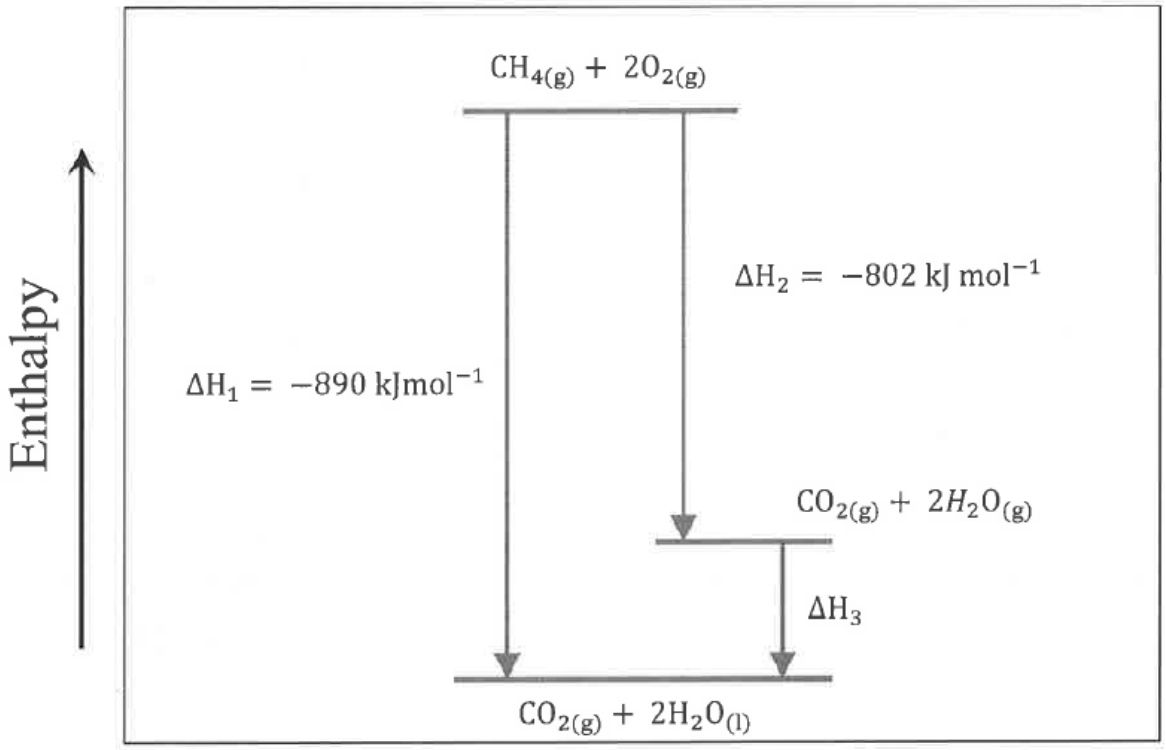
C - explicit comparison missing
IB – ionic bonding
IS – ionic structure
MB – metallic bonding
MS – metallic structure
D – lacks depth

Sample answer

Metallic elements' structure involves a 3-D lattice of metal cations in a sea of delocalised electrons. The bonding is due to the electrostatic attraction between the metal's positive nuclei and the electrons. Ionic compounds also have a 3D lattice structure – but they have an array of repeating units of alternating cations and anions. These ions are also bonded by electrostatic attraction but this time it is between the fixed cations and anions and there are no free electrons. This ionic bonding makes the lattice structure very rigid (shatters when hit) compared to the easily malleable lattice structure of metals (as the free electrons can readily relocate to ensure the metallic bonds stay in place as the metal is beaten).

Q66

Hess's Law states that the total enthalpy change during the complete course of a chemical reaction is the same irrespective of the pathway taken i.e. whether the reaction is made in one step or in several steps. Consider the following example for the complete combustion of methane.



(a) If Hess's Law holds for the above example, calculate ΔH_3.

2 marks - calculating -88 kJ/mol

1 mark for +88 kJ/mol **2**

Q67

With reference to the tabulated first ionisation energies below, explain the differences in reactivity between potassium and rubidium.

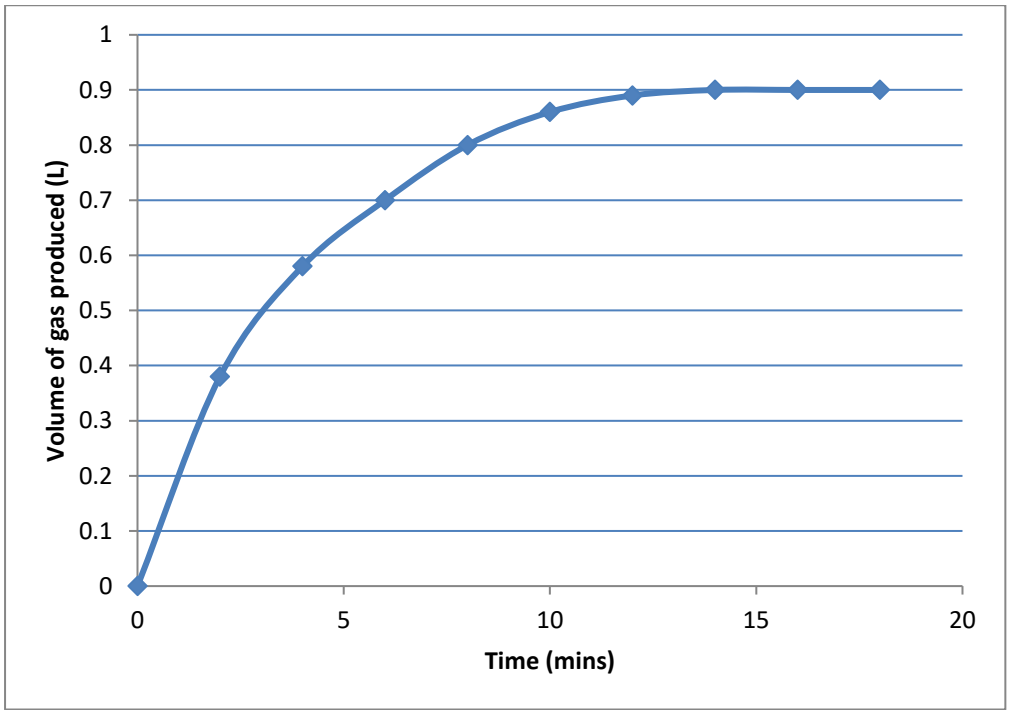
Metal	First Ionisation Energy ($kJ\ mol^{-1}$)
Potassium	425
Rubidium	403

- Explain first ionization energy reduced
- Correlate first ionization energy ↑ to increased reactivity
- refer to atom with rubidium having lower ionization energy and hence higher reactivity.

3

Q68

Excess copper(II) carbonate was placed in a conical flask and 100.0 mL of dilute sulfuric acid was added. A reaction occurred and the gas produced was collected. The volume of gas collected at 100 kPa and 25 °C is shown in the graph below.



Calculate the concentration of the sulfuric acid.

3

Equation 1 Mark
$CuCO_{3(s)} + H_2SO_{4(aq)} \Rightarrow CuSO_{4(aq)} + CO_{2(g)} + H_2O_{(l)}$.

1 Mark $n_{(CO_2)} = \frac{0.90}{24.79} = 0.0360 \text{ Mol}$

1 Mark $n_{H_2SO_4} = n_{CO_2} = 0.0360 \text{ Mol}$.

$[H_2SO_4] = \frac{0.0360}{0.100} = 0.360 \text{ M}$.

Correct units

Q69

Solutions of $FeCl_{2(aq)}$ oxidise easily in the presence of oxygen to produce $FeCl_{3(aq)}$. Iron filings can be added to stabilise these solutions by reducing any $FeCl_{3(aq)}$ formed back to $FeCl_{2(aq)}$ according to the following equation.

$$Fe_{(s)} + 2FeCl_{3(aq)} \longrightarrow 3FeCl_{2(aq)}$$

(a) Write the net ionic equation for this reaction.

$Fe_{(s)} + 2Fe^{3+}_{(aq)} \rightarrow 3Fe^{2+}_{(aq)}$ 1

(b) Write the reduction and oxidation half equations for these reactions.

(i) Reduction

$Fe^{3+}_{(aq)} + e^- \rightarrow Fe^{2+}_{(aq)}$ 1

(ii) Oxidation

$Fe_{(s)} \rightarrow Fe^{2+}_{(aq)} + 2e^-$ 1

(c) Calculate the mass of $FeCl_3$ can be reduced completely to $FeCl_2$ by 1.00 g of $Fe_{(s)}$.

$n_{Fe} = \frac{1.00}{55.85} = 0.01791$ mol 4

$n_{FeCl_3} = 2 \times n_{Fe} = \frac{2.00}{55.85} = 0.03581$ mol

$m_{FeCl_3} = n \times M = \frac{2.00}{55.85} \times 162.2$

= ~~4.5711~~ 5.81g

= ~~4.59~~ to 3 s.f

Q70

2.67 L of vapourised phosphorus molecules are reacted with 8.01 L of oxygen gas at a constant temperature and pressure to produce 2.67 L of a gaseous oxide of phosphorus having a molar mass of 220 g mol^{-1}.

(a) Balance the given equation below for the reaction.

$$P_{x(g)} + 3O_{2(g)} \rightarrow P_xO_{y(g)}$$ 1

(b) Determine the formula of the oxide of phosphorus. Show working. 2

1 mark.

y = number of oxygens = 2×3 = 6.

mass of 6 oxygens = 6×16 = 96

∴ mass of phosphorus = 220 − 96 = 124

number of phosphorus = $\frac{124}{31}$ = 4

1 mark. Formula = P_4O_6.

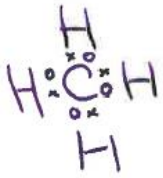
(c) Determine the molecular formula of the vapourised phosphorus molecules. 1

P_4.

Q71

(a) Construct Lewis dot diagrams of the following molecules

(i) methane

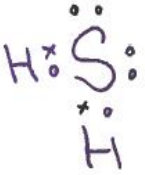


1

(ii) water

1

(iii) hydrogen sulfide (H_2S)



1

(b) Explain why the boiling points of water and hydrogen sulfide differ.

3

(1) Water has hydrogen bonding

(2) H_2S has dipole - dipole + dispersion

+ ~~majority~~ + had to say dipole dipole

(3) more energy to disrupt waters intermolecular attraction therefore higher melting point.

Q72

In an experiment, a boy added 8.00 g of ammonium nitrate to 100 g of water.

(a) If the $\Delta_{sol}H$ for ammonium nitrate is + 25.41 kJ mol^{-1} and the water was initially 25.0 °C, calculate the final temperature of the resulting solution. 3

$n_{NH_4NO_3} = \frac{8.0}{80.052}$ (1)

$= 0.099935$

$q = mc\Delta T$

$-2539.348 = 100 \times 4.18 \times \Delta T$

$\Delta H_{sol} = \frac{-q}{n}$

$\Delta T = \frac{-2539.348}{4.18}$

$254100 = \frac{-q}{n}$ (1)

$= -6.074996$

$\therefore q = -2539.348\ J$

$T_F - T_i = \Delta T$

$T_F = 25 - 6.074996$

$= 18.9\ °C$ (1)

(b) The boy actually measured a final temperature of 22.1 °C. Suggest two possible reasons as to why there is a difference between these results. 2

(1) temperature was gained from the surroundings

(2) impurities in Ammonium nitrate

NOTE: for a) many used 4.18×10^3 but still left ΔH in kJ which gave the wrong value.

b) poor equipment and misreadings not accepted
Have to assume the experiment was conducted properly and carefully.

Q73

Write balanced chemical equations for the following reactions, including states:
One states mistake allowable if incorrect state given

(a) Magnesium oxide with hydrochloric acid.

$MgO_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$ 1

(b) Sodium hydrogen carbonate with sulfuric acid.

$2NaHCO_{3(s)} + H_2SO_{4(aq)} \rightarrow Na_2SO_{4(aq)} + 2H_2O_{(l)} + 2CO_{2(g)}$ 1
(or (aq))

(c) Sodium with water.

$2Na_{(s)} + 2H_2O_{(l)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$ 1

↑ many said this formed Na_2O.

Q74

Pentane and water are immiscible liquids that have the properties below.

	Boiling Point (°C)	Density (g cm^{-3})
Pentane	36	0.6
Water	100	1.0

Assess the relative suitability of distillation or a separating funnel as techniques to separate pentane and water.

Unless negated by an incorrect fact

(1) = why separating funnel would work 3

(1) = why distillation would work

(1) = assessment statement.

- Separating or distillation or both but a reason.

Overall wholistically marked.

eg. densities too close.

Q75

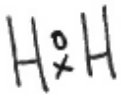
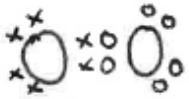
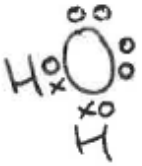
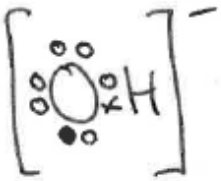
Complete the following table.

Name of Element or Ion	Protons	Charge	Electron Configuration
Magnesium	12	+2	2.8
Phosphorus	15	0	2.8.5
Chlorine ion or chloride	17	-1	2.8.8

bright = 3 marks
4-5 right = 2 marks
2-3 right = 1 marks
0-1 right = 0 marks

Q76

Draw Lewis electron dot diagrams for the following materials.

H_2	O_2
	
H_2O	OH^-
	

- Boys should make certain electrons are clear and paired.
- Many had their atoms too far apart.

4

Q77

A sample of processed meat was placed in a container of known mass and dried in an oven until the mass no longer reduced. The various masses were recorded in the table below.

Item	Mass (g)
Container	21.3
Container and undried meat sample	24.2
Container and dried meat sample	23.4

Determine the percentage water by mass in the original sample of processed meat.

$24.2 - 23.4 = 0.8$ g of water (1)

$24.2 - 21.3 = 2.9$ g of undried meat (1)

$\frac{0.8}{2.9} \times 100 = 27.6\ \%$ (1)

3

Q78

(a) Write a balanced equation for the reaction of aluminium with sulfuric acid.

$2Al + 3H_2SO_4 \rightarrow Al_2(SO_4)_3 + 3H_2$

States not required.

1

(b) Write and identify the reduction and oxidation half equations for the reaction of aluminium with sulfuric acid.

Reduction: $2H^+ + 2e \rightarrow H_2$

Oxidation: $Al \rightarrow Al^{3+} + 3e$

2

Q79

Potassium is ductile while potassium chloride is brittle. Explain the difference in these properties in terms of the structure and bonding of the two materials.

Marked holistically

* K is a metal made of a 3D lattice of cations in a sea of delocalised electrons MS
* When a metallic structure is distorted the cations are moved, & so the electrons flow in order to neutralise/stabilise the structure → ductile. EF
* KCl – is an ionic lattice of alternating cations & anions. 1 S
* As you distort the structure the cations align with cations & the anions with anions, & thus repel → brittle 1R

4

Q80

A pupil was given three metal samples (lead, silver and magnesium), but they forgot to label the samples. The pupil then conducted the following tests.

Metal	Reaction with H_2O	Reaction with acid	Reaction with oxygen
1	No Visible Reaction	No Visible Reaction	No Visible Reaction
2	White coating formed in near-boiling water	Reacted vigorously with cold H_2SO_4	Burned readily as a thin foil
3	No Visible Reaction	Reacted slowly with warm H_2SO_4	Formed a red/brown layer when heated in air

Identify the metals 1, 2 and 3.

Metal 1: Silver

Metal 2: Magnesium

Metal 3: Lead.

2

Q81

Five **consecutive** elements in increasing atomic number have **first** ionisation energies as shown in the table below.

Element	W	V	X	Y	Z
First ionisation energy (kJ / mol)	1260	1520	418	590	632

(a) Define First Ionisation Energy

The amount of energy (per mole) required to remove an electron from an atom. (one mole of) atom **1**

(b) Identify which element/(s) (W-Z) would be most likely to;

(i) be a noble gas.

V **1**

(ii) form an ion with a 1+ charge.

X **1**

(iii) be metals.

X + Y + Z **1**

(iv) exist as a diatomic molecule.

W **1**

(v) react most vigorously with dilute hydrochloric acid.

X **1**

Q82

Explain why atomic radii decrease as you move along a Period of the Periodic Table but increase as you move down a Group.

Marks	Description
4	• Discusses that across a period: increased numbers of electrons go into same shell; more protons yet same shielding; hence smaller radius. • Discusses that down group; new shell; even though more protons and electrons, also more electron shielding from inner shell electrons, hence larger radius, • Gives logical, clear progression and uses good scientific language.
3	• As per 4 marks, but with one item incorrect / missing
2	• Provides 2 items listed for 1 mark
1	• Mentions any chemistry principle correctly from 4 marks list.

Q83

Complete the table below by using the physical properties in the table to classify the following elements as metals, non-metals or semi-metals and solids, liquids or gases.

	Melting Point (°C)	Boiling Point (°C)	Density (g cm^{-3})	Electrical conductivity (MS m^{-1})	Metal/Non-metal/Semi-metal	Solid/Liquid/ Gas at 300°C
A	63	760	0.86	14	*M*	*L*
B	44	280	1.82	10^{-15}	*NM*	*G*
C	-39	357	13.5	1.0	*SM or M*	*L*
D	937	2830	5.3	10^{-4}	*SM*	*S*

<4 – 0 mark
4-5 – 1 mark
6-7 – 2 marks
8 – 3 marks

3

Q84

Chromium is often found in the Earth's crust as chromite, $FeCr_2O_4$. The production of chromium metal from chromite involves a series of chemical reactions:

$4\ FeCr_2O_{4(s)} + 8\ Na_2CO_{3(s)} + 7\ O_{2(g)} \rightarrow 8\ Na_2CrO_{4(s)} + 2\ Fe_2O_{3(s)} + 8\ CO_{2(g)}$

$2\ Na_2CrO_{4(s)} + H_2SO_{4(aq)} \rightarrow Na_2Cr_2O_{7(s)} + Na_2SO_{4(aq)} + H_2O_{(l)}$

$Na_2Cr_2O_{7(s)} + 2\ C_{(s)} \rightarrow Cr_2O_{3(s)} + Na_2CO_{3(s)} + CO_{(g)}$

$Cr_2O_{3(s)} + 2\ Al_{(s)} \rightarrow Al_2O_{3(s)} + 2\ Cr_{(s)}$

A 210.0 g ore sample containing 75.40% chromite by mass is processed through this series of chemical reactions.

(a) Calculate the mass of chromite, $FeCr_2O_4$, present in the 210.0 g ore sample.

$m(FeCr_2O_4) = 210.0\,g \times \frac{75.40}{100.0} = 158.3\,g$ 1

(b) Calculate the mass of carbon dioxide gas produced when chromium is produced from the 210.0 g ore sample by this process.

$n(FeCr_2O_4) = \frac{158.3\,g}{223.85\,g\,mol^{-1}} = 0.7073\,mol$ (1)

$\therefore n(CO_2) = 1.415\,mol$ (1)

$\therefore m(CO_2) = 1.415\,mol \times 44.01\,g\,mol^{-1}$

$= 62.26\,g$ (1) 3

Question continued

(c) Calculate the mass of chromium metal produced in this process using the 210.0 g sample.

$m(Cr) = 158.3\,g \times \frac{2 \times 52.00}{223.85} = 73.56\,g$ 2

OR

$n(Cr) = 2\,n(FeCr_2O_4) = 1.415\,mol$ (1)

$\therefore m(Cr) = 1.415\,mol \times 52.00\,g\,mol^{-1} = 73.56\,g$ (1)

(d) Calculate the number of aluminium atoms consumed in this process.

$n(Al) = 1.415\,mol$ 1

$\therefore$ # Al atoms $= 1.415\,mol \times 6.022 \times 10^{23}\,mol^{-1}$

$= 8.519 \times 10^{23}$.

Q85

In 1962, the synthesis of the first binary compound of a noble gas was reported in the Journal of the American Chemical Society. Decomposition of this colourless solid compound was reported to be give rise to 0.2507 g xenon and 0.1435 g fluorine by mass. Calculate the empirical formula of this compound.

$n(Xe) = \frac{0.2507\,g}{131.3\,g\,mol^{-1}} = 1.909 \times 10^{-3}\,mol$ (1) 3

either $n(F) = \frac{0.1435\,g}{19.00\,g\,mol^{-1}} = 7.553 \times 10^{-3}\,mol$ (1)

$n(F_2) = \frac{0.1435\,g}{38.00\,g\,mol^{-1}} = 3.776 \times 10^{-3}\,mol$

Then $\frac{n(F)}{n(Xe)} = 3.956$ or $\frac{n(F_2)}{n(Xe)} = 1.978$

i.e. $XeF_{4(s)}$. (1)

Q86

Argyrodite is a rare mineral that contains only three elements; silver, sulfur and an unknown element **X**. It has a molar mass of between 1000 $gmol^{-1}$ and 1500 $gmol^{-1}$.

The first step to extract silver, sulfur and **X** from the mineral involves roasting the mineral by heating it with oxygen. When 100.0 g of argyrodite is heated with a stoichiometric ratio of 19.77 L of oxygen (measured at 100 kPa and 25 °C) three binary compounds are obtained; a black solid, a white solid, and 13.18 L of sulfur dioxide gas (measured at 100 kPa and 25 °C). This black solid can then be heated with carbon monoxide to produce solid silver and 8.789 L of a colourless gas (measured at 100 kPa and 25 °C).

Use this information to identify element **X** and the empirical formula of argyrodite, showing all working and logic.

5

① one correct calculation or reasonable chemical equation

① 3 molar calculations from the gas volumes (O_2, SO_2, CO_2)

① correct Ag : S ratio (4:3)

① correct deduction relating to charge on X or that Ag_8S_6 most likely

① X = germanium

argyrodite = Ag_8GeS_6

Q87

Compound **A** is a white insoluble mineral made of four elements. When 10.000 g of compound **A** is reacted with 2 M HCl, 2.6886 L of CO_2 (measured at 25 °C and 100 kPa), is evolved. Na_2SO_4 is then added to the solution forming 7.383 g of compound **B** as a precipitate; compound **C** remains in solution.

The solution of compound **C** is neutralised with 2 M NaOH forming 3.1628 g of a precipitate of compound **D**, which was filtered. The 3.1628 g of Compound **D** was then heated to produce 2.1859 g of compound **E** and water. Compound **E** was heated at 2300 °C with excess carbon to give CO and 1.3183 g of pure metal **F**.

What are the formulae of compounds **A-F**? Show working.

6

(1) A must contain a carbonate as CO_2 produced.

$n_{CO_2} = 0.10845$ moles.

→ Then work bottom up.

mass of O_2 lost = 2.1859 − 1.3183

= 0.8676

$\therefore n_O = 0.054225$

so if 1:1 oxygen : metal then 0.054225 moles of metal.

$\therefore$ Molar mass metal = $\frac{\text{mass pure}}{\text{moles of O}} = \frac{1.3183}{0.054225} = 24.31$

$\therefore$ Mg. (2)

A = carbonate

B = sulfate

C = sulfate or chloride.

D = hydroxide

E = Oxide

F = pure metal.

so F = Mg

E = MgO (2) (1)

D = $Mg(OH)_2$

C = $MgSO_4$ or $MgCl_2$ (1)

ratio Mg : CO_3

1 : 2

$\therefore$ A = $Mg(CO_3)_2X$

B = XSO_4

assuming X has a minus 2 charge.

$\therefore$ 1:1

so moles X = 0.054224

$\therefore M_B = \frac{7.383}{0.054224}$

= 136.149, CRMR

$M_w SO_4 = 96.07$ $\therefore M_w X = 40.079 = Ca$

(1) (1)

$B_a = CaSO_4$

(1) A = $MgCa(CO_3)_2$

Q88

Wegscheiderite is an evaporite mineral found at the Green River Formation in Wyoming, USA. Elemental analysis shows wegscheiderite to contain four different elements. When 10.000 g of wegscheiderite is treated with excess hydrochloric acid, 4.917 g of carbon dioxide is given off. In a separate experiment, 0.1000 g of wegscheiderite is dissolved in water and treated with excess of a solution of uranyl zinc acetate ($UO_2Zn(CH_3COO)_4$). A precipitate of $(UO_2)_3ZnNa(CH_3COO)_9{\cdot}6H_2O$ (molar mass 1537.9 g mol^{-1}) is produced, which after purification has a mass of 2.148 g.

Calculate the empirical formula of wegscheiderite, showing all working and logic.

$n(CO_2) = \frac{4.917\,g}{44.01\,g\,mol^{-1}} = 0.1117\,mol$ 5

$n((UO_2)_3ZnNa(CH_3COO)_9{\cdot}6H_2O) = \frac{2.148\,g}{1537.9\,g\,mol^{-1}} = 1.397\times10^{-3}\,mol$

$\therefore n(Na^+ \text{ in } 0.1\,g \text{ Wegscheiderite}) = 1.397\times10^{-3}\,mol$

$\therefore n(Na^+ \text{ in } 10\,g \text{ Wegscheiderite}) = 0.1397\,mol.$

$\therefore \frac{n(Na^+ \text{ in } 10g \text{ Wegscheiderite})}{n(CO_2 \text{ from } 10g \text{ Wegscheiderite})} = \frac{0.1397\,mol}{0.1117\,mol} = 1.250.$

This suggests $5Na^+ : 4CO_2$.

The CO_2 comes from CO_3^{2-} or HCO_3^- reacting with acid.

To balance charges, need $3\times HCO_3^-$ & $1\times CO_3^{2-}$ for $5Na^+$.

This can and should be checked / derived from mass data:

In 10g Wegscheiderite, $m(Na) = 0.1397\,mol \times 22.99\,g\,mol^{-1}$

$= 3.211\,g$

$m(\text{"}CO_3\text{"} \rightarrow \text{from } CO_3^{2-} \text{ or } HCO_3^-) = n(CO_2) \times (12.01 + 3\times16.00)$

$= 6.705\,g$

$\therefore m(\text{remaining}) = 10.000\,g - 9.916\,g = 0.0844\,g.$

Such a small mass is consistent with H; $n(H) = \frac{0.0844\,g}{1.008\,g\,mol^{-1}}$

$= 0.0837\,mol$

So $n(Na) : n(C) : n(O) : n(H) \rightarrow 5 : 4 : 8 : 3$

i.e. $Na_5(HCO_3)_3CO_3(s)$.

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FORMULAE SHEET

$$n = \frac{m}{MM} \qquad c = \frac{n}{v} \qquad PV = nRT$$

$$q = mC\Delta T \qquad \Delta G^\circ = \Delta H^\circ - T\Delta S^\circ \qquad \text{pH} = -\log_{10}[\text{H}^+]$$

$$pK_a = -\log_{10}[K_a] \qquad A = \varepsilon lc = \log_{10}\frac{I_o}{I}$$

Avogadro constant, N_A ..... 6.022×10^{23} mol^{-1}

Volume of 1 mole ideal gas: at 100 kPa and

at 0°C (273.15 K) ..... 22.71 L

at 25°C (298.15 K) ..... 24.79 L

Gas constant ..... 8.314 J mol^{-1} K^{-1}

Ionisation constant for water at 25°C (298.15 K), K_w ..... 1.0×10^{-14}

Specific heat capacity of water ..... 4.18×10^3 J kg^{-1} K^{-1}

DATA SHEET

Solubility constants at 25°C

Compound	K_{sp}	*Compound*	K_{sp}
Barium carbonate	2.58×10^{-9}	Lead(II) bromide	6.60×10^{-6}
Barium hydroxide	2.55×10^{-4}	Lead(II) chloride	1.70×10^{-5}
Barium phosphate	1.3×10^{-29}	Lead(II) iodide	9.8×10^{-9}
Barium sulfate	1.08×10^{-10}	Lead(II) carbonate	7.40×10^{-14}
Calcium carbonate	3.36×10^{-9}	Lead(II) hydroxide	1.43×10^{-15}
Calcium hydroxide	5.02×10^{-6}	Lead(II) phosphate	8.0×10^{-43}
Calcium phosphate	2.07×10^{-29}	Lead(II) sulfate	2.53×10^{-8}
Calcium sulfate	4.93×10^{-5}	Magnesium carbonate	6.82×10^{-6}
Copper(II) carbonate	1.4×10^{-10}	Magnesium hydroxide	5.61×10^{-12}
Copper(II) hydroxide	2.2×10^{-20}	Magnesium phosphate	1.04×10^{-24}
Copper(II) phosphate	1.40×10^{-37}	Silver bromide	5.35×10^{-13}
Iron(II) carbonate	3.13×10^{-11}	Silver chloride	1.77×10^{-10}
Iron(II) hydroxide	4.87×10^{-17}	Silver carbonate	8.46×10^{-12}
Iron(III) hydroxide	2.79×10^{-39}	Silver hydroxide	2.0×10^{-8}
Iron(III) phosphate	9.91×10^{-16}	Silver iodide	8.52×10^{-17}
		Silver phosphate	8.89×10^{-17}
		Silver sulfate	1.20×10^{-5}

Aylward and Findlay, *SI Chemical Data* (5th Edition) is the principal source of data for this examination paper. Some data may have been modified for examination purposes.

Some standard potentials

$K^+ + e^-$	$\rightleftharpoons$	$K(s)$	–2.94 V
$Ba^{2+} + 2e^-$	$\rightleftharpoons$	$Ba(s)$	–2.91 V
$Ca^{2+} + 2e^-$	$\rightleftharpoons$	$Ca(s)$	–2.87 V
$Na^+ + e^-$	$\rightleftharpoons$	$Na(s)$	–2.71 V
$Mg^{2+} + 2e^-$	$\rightleftharpoons$	$Mg(s)$	–2.36 V
$Al^{3+} + 3e^-$	$\rightleftharpoons$	$Al(s)$	–1.68 V
$Mn^{2+} + 2e^-$	$\rightleftharpoons$	$Mn(s)$	–1.18 V
$H_2O + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g) + OH^-$	–0.83 V
$Zn^{2+} + 2e^-$	$\rightleftharpoons$	$Zn(s)$	–0.76 V
$Fe^{2+} + 2e^-$	$\rightleftharpoons$	$Fe(s)$	–0.44 V
$Ni^{2+} + 2e^-$	$\rightleftharpoons$	$Ni(s)$	–0.24 V
$Sn^{2+} + 2e^-$	$\rightleftharpoons$	$Sn(s)$	–0.14 V
$Pb^{2+} + 2e^-$	$\rightleftharpoons$	$Pb(s)$	–0.13 V
$H^+ + e^-$	$\rightleftharpoons$	$\frac{1}{2}H_2(g)$	0.00 V
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons$	$SO_2(aq) + 2H_2O$	0.16 V
$Cu^{2+} + 2e^-$	$\rightleftharpoons$	$Cu(s)$	0.34 V
$\frac{1}{2}O_2(g) + H_2O + 2e^-$	$\rightleftharpoons$	$2OH^-$	0.40 V
$Cu^+ + e^-$	$\rightleftharpoons$	$Cu(s)$	0.52 V
$\frac{1}{2}I_2(s) + e^-$	$\rightleftharpoons$	I^-	0.54 V
$\frac{1}{2}I_2(aq) + e^-$	$\rightleftharpoons$	I^-	0.62 V
$Fe^{3+} + e^-$	$\rightleftharpoons$	Fe^{2+}	0.77 V
$Ag^+ + e^-$	$\rightleftharpoons$	$Ag(s)$	0.80 V
$\frac{1}{2}Br_2(l) + e^-$	$\rightleftharpoons$	Br^-	1.08 V
$\frac{1}{2}Br_2(aq) + e^-$	$\rightleftharpoons$	Br^-	1.10 V
$\frac{1}{2}O_2(g) + 2H^+ + 2e^-$	$\rightleftharpoons$	H_2O	1.23 V
$\frac{1}{2}Cl_2(g) + e^-$	$\rightleftharpoons$	Cl^-	1.36 V
$\frac{1}{2}Cr_2O_7^{2-} + 7H^+ + 3e^-$	$\rightleftharpoons$	$Cr^{3+} + \frac{7}{2}H_2O$	1.36 V
$\frac{1}{2}Cl_2(aq) + e^-$	$\rightleftharpoons$	Cl^-	1.40 V
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons$	$Mn^{2+} + 4H_2O$	1.51 V
$\frac{1}{2}F_2(g) + e^-$	$\rightleftharpoons$	F^-	2.89 V

PERIODIC TABLE OF THE ELEMENTS

1 H 1.008 Hydrogen																	2 He 4.003 Helium
3 Li 6.941 Lithium	4 Be 9.012 Beryllium											5 B 10.81 Boron	6 C 12.01 Carbon	7 N 14.01 Nitrogen	8 O 16.00 Oxygen	9 F 19.00 Fluorine	10 Ne 20.18 Neon
11 Na 22.99 Sodium	12 Mg 24.31 Magnesium											13 Al 26.98 Aluminium	14 Si 28.09 Silicon	15 P 30.97 Phosphorus	16 S 32.07 Sulfur	17 Cl 35.45 Chlorine	18 Ar 39.95 Argon
19 K 39.10 Potassium	20 Ca 40.08 Calcium	21 Sc 44.96 Scandium	22 Ti 47.87 Titanium	23 V 50.94 Vanadium	24 Cr 52.00 Chromium	25 Mn 54.94 Manganese	26 Fe 55.85 Iron	27 Co 58.93 Cobalt	28 Ni 58.69 Nickel	29 Cu 63.55 Copper	30 Zn 65.38 Zinc	31 Ga 69.72 Gallium	32 Ge 72.64 Germanium	33 As 74.92 Arsenic	34 Se 78.96 Selenium	35 Br 79.90 Bromine	36 Kr 83.80 Krypton
37 Rb 85.47 Rubidium	38 Sr 87.61 Strontium	39 Y 88.91 Yttrium	40 Zr 91.22 Zirconium	41 Nb 92.91 Niobium	42 Mo 95.96 Molybdenum	43 Tc Technetium	44 Ru 101.1 Ruthenium	45 Rh 102.9 Rhodium	46 Pd 106.4 Palladium	47 Ag 107.9 Silver	48 Cd 112.4 Cadmium	49 In 114.8 Indium	50 Sn 118.7 Tin	51 Sb 121.8 Antimony	52 Te 127.6 Tellurium	53 I 126.9 Iodine	54 Xe 131.3 Xenon
55 Cs 132.9 Caesium	56 Ba 137.3 Barium	57–71 Lanthanoids	72 Hf 178.5 Hafnium	73 Ta 180.9 Tantalum	74 W 183.9 Tungsten	75 Re 186.2 Rhenium	76 Os 190.2 Osmium	77 Ir 192.2 Iridium	78 Pt 195.1 Platinum	79 Au 197.0 Gold	80 Hg 200.6 Mercury	81 Tl 204.4 Thallium	82 Pb 207.2 Lead	83 Bi 209.0 Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon
87 Fr Francium	88 Ra Radium	89–103 Actinoids	104 Rf Rutherfordium	105 Db Dubnium	106 Sg Seaborgium	107 Bh Bohrium	108 Hs Hassium	109 Mt Meitnerium	110 Ds Darmstadtium	111 Rg Roentgenium	112 Cn Copernicium	113 Nh Nihonium	114 Fl Flerovium	115 Mc Moscovium	116 Lv Livermorium	117 Ts Tennessine	118 Og Oganesson

KEY

Atomic Number	79
Symbol	Au
Standard Atomic Weight	197.0
Name	Gold

Lanthanoids

57 La 138.9 Lanthanum	58 Ce 140.1 Cerium	59 Pr 140.9 Praseodymium	60 Nd 144.2 Neodymium	61 Pm Promethium	62 Sm 150.4 Samarium	63 Eu 152.0 Europium	64 Gd 157.3 Gadolinium	65 Tb 158.9 Terbium	66 Dy 162.5 Dysprosium	67 Ho 164.9 Holmium	68 Er 167.3 Erbium	69 Tm 168.9 Thulium	70 Yb 173.1 Ytterbium	71 Lu 175.0 Lutetium

Actinoids

89 Ac Actinium	90 Th 232.0 Thorium	91 Pa 231.0 Protactinium	92 U 238.0 Uranium	93 Np Neptunium	94 Pu Plutonium	95 Am Americium	96 Cm Curium	97 Bk Berkelium	98 Cf Californium	99 Es Einsteinium	100 Fm Fermium	101 Md Mendelevium	102 No Nobelium	103 Lr Lawrencium

Standard atomic weights are abridged to four significant figures.

Elements with no reported values in the table have no stable nuclides.

Information on elements with atomic numbers 113 and above is sourced from the International Union of Pure and Applied Chemistry Periodic Table of the Elements (November 2016 version).

The International Union of Pure and Applied Chemistry Periodic Table of the Elements (February 2010 version) is the principal source of all other data. Some data may have been modified.