VCE CHEMISTRY 2013

YEAR 11 TRIAL EXAM

Unit 1 & Unit 2
Reading time: 15 minutes
Writing time: 2 hours 30 minutes

Section	*Number of questions*	*Number of questions to be answered*	*Number of marks*
A	30	30	30
B	13	13	92
			Total 122

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http://www.vcaa.vic.edu.au/Documents/exams/chemistry/2012/2012chem1-w.pdf *Page 28*

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STUDENT NUMBER

									Letter
Figures									
Words									

Student Name.....……..... .....

VCE Chemistry 2013 Year 11 Trial Exam Unit 1/2

Student Answer Sheet

Instructions for completing test. Use only a 2B pencil. If you make a mistake, erase it and enter the correct answer. Marks will not be deducted for incorrect answers.

Write your answers to the Short Answer Section in the space provided directly below the question. There are 30 Multiple Choice questions to be answered by circling the correct letter in the table below.

Question 1	A	B	C	D	*Question 2*	A	B	C	D
Question 3	A	B	C	D	*Question 4*	A	B	C	D
Question 5	A	B	C	D	*Question 6*	A	B	C	D
Question 7	A	B	C	D	*Question 8*	A	B	C	D
Question 9	A	B	C	D	*Question 10*	A	B	C	D
Question 11	A	B	C	D	*Question 12*	A	B	C	D
Question 13	A	B	C	D	*Question 14*	A	B	C	D
Question 15	A	B	C	D	*Question 16*	A	B	C	D
Question 17	A	B	C	D	*Question 18*	A	B	C	D
Question 19	A	B	C	D	*Question 20*	A	B	C	D
Question 21	A	B	C	D	*Question 22*	A	B	C	D
Question 23	A	B	C	D	*Question 24*	A	B	C	D
Question 25	A	B	C	D	*Question 26*	A	B	C	D
Question 27	A	B	C	D	*Question 28*	A	B	C	D
Question 29	A	B	C	D	*Question 30*	A	B	C	D

VCE Chemistry 2013 Year 11 Trial Exam Unit 1/2

SECTION A – Multiple Choice Questions

(30 marks, 36 minutes)

This section contains 30 multiple choice questions.
For each question, choose the response that is correct or best answers the question.
Indicate your answer on the answer sheet provided.
*(Choose only **one** answer for each question.)*

Question 1
Boron has two naturally occurring isotopes ^{10}B and ^{11}B. The abundance of the lighter isotope would be about
A. 20 %.
B. 40 %.
C. 60 %.
D. 80 %.

Question 2
Compared to phosphorous, bismuth would
A. exhibit a more non-metallic character.
B. have a higher electronegativity.
C. exhibit a more metallic character.
D. have a smaller atomic radius.

Question 3
In which one of the following compounds would the percentage by mass of lithium be the **least**?
A. Lithium nitrate, $LiNO_3$.
B. Lithium hydroxide, LiOH.
C. Lithium sulfate, Li_2SO_4.
D. Lithium chloride, LiCl.

Question 4
An ion with a double negative charge contained 36 electrons and 42 neutrons. The mass number for this atom would be
A. 78
B. 76
C. 82
D. 80

Question 5
Which one of the following electronic configurations would be for an atom in its ground state?

A. $1s^2 2s^2 2p^6 3s^1 3p^6$
B. $1s^2 2s^2 2p^6 3s^2 3p^6 3d^1$
C. $1s^2 2s^2 2p^4 3s^2 3p^4$
D. $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1$

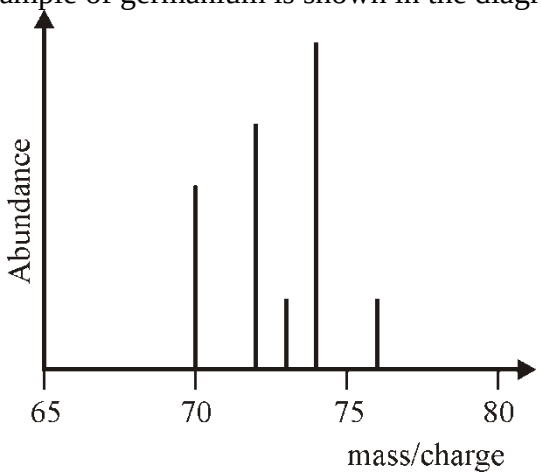
Question 6
The number of atoms present in 8.0 g of oxygen gas, O_2, would be the same as the number of

A. atoms present in 1.0 g of hydrogen gas.
B. molecules present in 9.0 g of water.
C. atoms present in 4.0 g of methane.
D. molecules present in 11.0 g of carbon dioxide.

Question 7
When a metal, X, was heated in oxygen, an oxide with the chemical formula XO_2 was formed. In an experiment, the mass of oxide formed when 2.146 g of the metal reacted was 3.579 g. The metal that reacted was

A. magnesium.
B. molybdenum.
C. tungsten.
D. titanium.

Question 8
The mass spectrum for a sample of germanium is shown in the diagram.



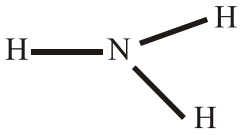
This mass spectrum shows that

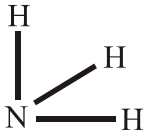
A. germanium atoms with 41 neutrons are not present in the sample.
B. the abundance of ^{72}Ge is twice that of ^{70}Ge.
C. germanium atoms with 43 neutrons are not present in the sample.
D. the abundance of ^{74}Ge is 100 %.

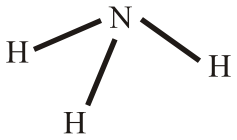
Question 9
When a sample of barium was heated in air, the mass of barium oxide, BaO, formed was 5.342 g. The mass of oxygen that reacted with the barium was
A. 0.558 g.
B. 4.784 g.
C. 1.115 g.
D. 0.278 g.

Question 10
The diagram that would best describe the arrangement of the atoms in ammonia, NH_3, would be

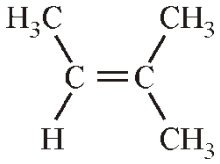
A.


B.


C.


D.


Question 11
The systematic name for the hydrocarbon whose structure is shown below is



A. pent-2-ene.
B. 2-methylbut-2-ene.
C. 2-methylbut-3-ene.
D. 2-methylbutyne.

Question 12
Which one of the following is **not** adequately explained by the ionic bonding model?
A. The electrical conductivity of ionic compounds in the solid state.
B. The hardness of ionic solids.
C. The solubility of various ionic compounds.
D. The electrical conductivity of ionic compounds in the molten state.

Question 13
A polymeric substance that is rigid and does not readily soften when heated will
A. consist of polymer chains that have extensive branching.
B. have extensive cross linking between the polymer chains.
C. consist of linear polymer chains with no branching.
D. have no cross linking between the polymer chains.

Question 14
When alkanes are completely burnt they produce
A. carbon monoxide and water.
B. carbon dioxide and water.
C. carbon monoxide, carbon dioxide and water.
D. carbon dioxide and hydrogen.

Question 15
In the structure of graphite there are
A. weak bonding interactions between the layers of carbon atoms.
B. dipolar interactions between the layers of carbon atoms.
C. weak bonding interactions between the carbon atoms in the layers.
D. covalent bonds between the layers of carbon atoms.

Question 16
The conjugate acid for the amide ion, NH_2^-, would be
A. NH_4^+
B. NH_3
C. H_3O^+
D. NH^{2-}

Question 17
In a redox reaction the
A. reductant will donate electrons and be reduced.
B. oxidant will donate electrons and be reduced.
C. oxidant will accept electrons and be oxidised.
D. reductant will donate electrons and be oxidised.

Question 18
50.0 mL of 1.00 M aqueous sodium hydroxide solution was diluted to 5.0 L with deionised water. The resultant pH of this solution when it was thoroughly mixed would be
A. 12
B. 2
C. 14
D. 10

Question 19
When added to an aqueous solution of iron(II) sulfate, $FeSO_4(aq)$, which one of the following solutions will **not** produce a precipitate?
A. Barium chloride, $BaCl_2(aq)$.
B. Sodium hydroxide, NaOH(aq).
C. Lithium carbonate, $Li_2CO_3(aq)$.
D. Ammonium nitrate, $NH_4NO_3(aq)$.

Question 20
The concentration of the ammonium ion in an aqueous solution of ammonium sulfate, $(NH_4)_2SO_4$, prepared by dissolving 7.932 g of solid solute in 250.0 mL of deionised water would be closest to

A. 0.24 M.
B. 0.12 M.
C. 0.48 M.
D. 0.06 M.

Question 21
When sodium chloride dissolves in water, the water molecules will form

A. dipole-dipole bonds with the sodium chloride.
B. hydrogen bonds with the sodium and chloride ions.
C. covalent bonds with the sodium chloride.
D. ion-dipole bonds with the sodium and chloride ions.

Question 22
The chemical equation that would best describe the reaction between solid magnesite, $MgCO_3$, and a dilute aqueous solution of nitric acid would be

A. $MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + CO_2(g)$
B. $MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l) + CO_2(g)$
C. $MgCO_3(s) + HNO_3(aq) \rightarrow MgNO_3(aq) + HCO_3^-(aq)$
D. $MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l)$

Question 23
A 1.287 g sample of a gas occupied a volume of 450 mL at STP. The gas in the sample would most likely be

A. $Cl_2(g)$.
B. $C_5H_8(g)$.
C. $SO_2(g)$.
D. $ClO_2(g)$.

Question 24
The reaction that occurs when potassium chlorate is heated in the presence of a catalyst, such as manganese(IV) oxide, can be described by the chemical equation

$$2KClO_3(s) \xrightarrow{MnO_2(s)} 2KCl(s) + 3O_2(g)$$

When a sample of potassium chlorate was heated, the mass of potassium chloride formed was 14.618 g. The volume of oxygen gas at SLC that would be produced would have been

A. 7.20 L.
B. 4.38 L.
C. 4.80 L.
D. 2.92 L.

Question 25
Which one of the following groups of gases lists those whose concentration in the atmosphere will be most affected by the use of fossil fuels in vehicles?
A. Oxygen, carbon dioxide and unburnt hydrocarbons.
B. Carbon dioxide, oxygen and nitrogen oxides.
C. Nitrogen oxides, unburnt hydrocarbons and carbon dioxide.
D. Unburnt hydrocarbons, nitrogen oxides and oxygen.

Question 26
A nitrogen gas cylinder has a volume of 55.7 L. The pressure of nitrogen in the cylinder at 15 °C was 18100 kPa. The mass of nitrogen gas in the cylinder would be
A. 22.6 kg.
B. 11.8 kg.
C. 5.9 kg.
D. 10.9 kg.

Question 27
The gas phase reaction between nitrogen(I) oxide and oxygen can be described by the chemical equation

$$2N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g)$$

The volume of nitrogen(I) oxide that would react with 364 mL of oxygen at the same temperature and pressure would be
A. 546 mL.
B. 121 mL.
C. 485 mL.
D. 243 mL.

Question 28
The most convenient method to produce a sample of oxygen gas in a laboratory would be to
A. obtain it by fractional distillation of liquid air.
B. catalytically decompose an aqueous solution of hydrogen peroxide.
C. react calcium carbonate with an aqueous acid solution.
D. catalytically decompose water.

Question 29
Photosynthesis is
A. one of the main processes in the carbon cycle that removes carbon from the atmosphere.
B. a process which uses light to bring about the formation of compounds.
C. one of the main processes in the carbon cycle that releases carbon dioxide into the atmosphere.
D. a process which plants use to synthesise cellulose.

Question 30

When water forms droplets on the surface of a solid,

A. the force of attraction between the water molecules is less than the force of attraction between the water molecules and the particles on the surface of the solid.

B. the force of attraction between the particles on the surface of the solid is less than the force of attraction between particles and the water molecules.

C. the force of attraction between the water molecules is greater than the force of attraction between the water molecules and the particles on the surface of the solid.

D. the force of attraction between the particles on the surface of the solid is the same as the force of attraction between the water molecules.

End of Section A

VCE Chemistry 2013 Year 11 Trial Exam Unit 1/2

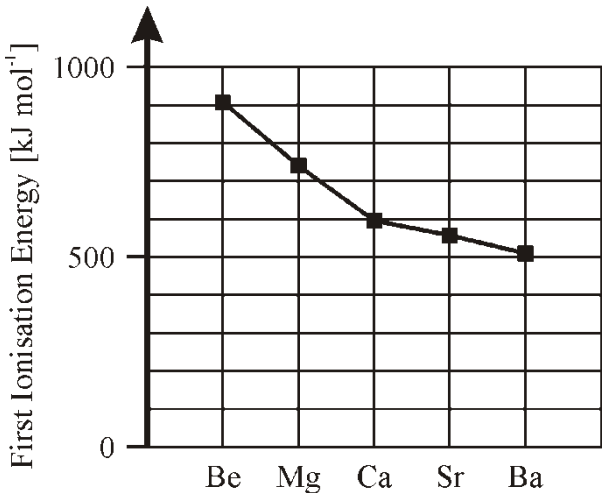
SECTION B – Short Answer Questions

(92 marks, 114 minutes)

This section contains thirteen questions, numbered 1 to 13.
All questions should be answered in the spaces provided.
The mark allocation and approximate time that should be spent on each question are given.

Question 1 (8 marks, 10 minutes)

a. The diagram below shows the first ionisation energy for the elements in Group 2 of the Periodic Table.



i. Briefly explain what the first ionisation energy involves at the atomic level. **1 mark**

ii. Explain why the observed trend, as shown in the diagram, in the first ionisation energies occurs. **2 marks**

iii. The first ionisation energy for magnesium is 744 kJ mol^{-1}. How would this compare to the first ionisation energy for sodium, Na, the previous element in the Periodic Table? **1 mark**

b. The second period of the Periodic Table includes the elements lithium, nitrogen and fluorine. The electronegativity of these elements increases moving across the period.

i. What is the electronegativity a measure of? **1 mark**

ii. Explain why the electronegativity of these elements increases moving across the Periodic Table. **1 mark**

c. Using its position in the Periodic Table, explain why arsenic displays characteristics that are between those of a metal and a non-metal element. **2 marks**

Question 2 (8 marks, 10 minutes)

a. The percentage by mass of carbon, hydrogen and nitrogen present in a compound was found to be 54.5 %, 13.7 % and 31.8 % respectively. The molar mass for the compound was found to be 88 g mol^{-1}.

i. Determine the empirical formula for this compound. **2 marks**

ii. Determine the molecular formula for this compound. **1 mark**

b. A student heated a sample of solid manganese(II) sulfate heptahydrate, $MnSO_4 \cdot 7H_2O$ in an open crucible to remove the water of crystallisation.

i. Write an appropriate chemical equation for what occurs when this solid is heated. **1 mark**

ii. Determine the percentage by mass that a sample would have decreased by following this process. **2 marks**

c. Mass spectral analysis of silver shows that it contains two isotopes with relative isotopic masses of 106.91 and 108.90. Determine the abundance of the heavier isotope in silver. **2 marks**

Question 3 (6 marks, 7 minutes)

a. Draw the structures for the following hydrocarbons. **2 marks**

i. 2,2-dimethylbutane **ii.** 2-methylpent-2-ene

b. Complete the following by stating how isomers of hydrocarbons affect each of the following. **4 marks**

Characteristic	**Affect of Isomers**
i. Molecular formula	
ii. Molecular structure	
iii. Chemical properties	
iv. Physical properties	

Question 4 (8 marks, 10 minutes)

a. Write the electronic configuration, in terms of sub-shells, for the following. **2 marks**

i. An iron(II) ion. **ii.** A silicon atom

b. Write the appropriate symbols for the following particles.

i. A neutral atom containing 88 neutrons with a mass number of 150. **1 mark**

ii. An ion containing 28 protons, 25 electrons and 33 neutrons. **1 mark**

c. Explain the contribution that James Chadwick made to the current atomic model. **2 marks**

d. Explain the processes that occur when an element is heated and then emits light of specific frequencies. **2 marks**

Question 5 (7 marks, 9 minutes)

a. Methanol, CH_3OH, will dissolve completely, is miscible, in water.

i. What type of bonding interactions occur within methanol? **1 mark**

ii. What type/s of bonding interactions occur between the methanol and water in aqueous solutions of methanol? **1 mark**

b. Explain why an ionic compound such as calcium chloride will weakly conduct an electric current in the molten and aqueous phases, but will not conduct an electric current in the solid state. **1 mark**

c. Draw the structures for the following molecules showing all bonding and non-bonding electrons and state whether the molecule has a permanent dipole.

i. Carbon disulfide, CS_2. **1 mark**

ii. Dichloromethane, CH_2Cl_2 **1 mark**

d. **i.** Draw the shape a water droplet would adopt when it is placed on a clean surface of polyethene. **1 mark**

ii. Explain why the water droplet behaves in the manner shown in the diagram drawn in **i.** above. **1 mark**

Question 6 (5 marks, 6 minutes)

a. How would bulky groups, such as the benzene rings in polystyrene, attached to the polymer chain affect the following properties of the polymer?

i. Density. **1 mark**

ii. Brittleness. **1 mark**

b. Draw a diagram to represent part of the structure of the polymer that would be produced from propene. **1 mark**

c. What is a copolymer and why are they used in preference for some applications? **2 marks**

Question 7 (8 marks, 10 minutes)

a. Use the kinetic molecular theory model to explain the following statements regarding gases.

i. "Hot air rises in a closed room while cold air sinks." **1 mark**

ii. "At constant temperature decreasing the volume occupied by a gas will result in an increase in pressure." **1 mark**

iii. "The total pressure of a gas mixture is the sum of the pressures of the gases that make up the mixture." **1 mark**

iv. "When a container with an odorous gas was opened in one corner of a room the odour of the substance spread throughout the room." **1 mark**

b. i. What reactants would be required to produce a sample of carbon dioxide in the laboratory? **1 mark**

ii. Write an appropriate chemical equation for the reaction that would occur during the laboratory preparation of carbon dioxide using the reactants selected in **i.** above. **1 mark**

iii. When the carbon dioxide produced in this reaction was bubbled through an aqueous solution of bromothymol blue indicator solution, it changed from a blue-green colour to a yellow colour, indicating the presence of an acid. Explain this observation with the use of appropriate chemical equations. **2 marks**

Question 8 (8 marks, 10 minutes)

A student was provided with an aqueous solution of ethanoic acid, CH_3COOH, and asked to determine the concentration of ethanoic acid present by carrying out a titration with a standardised aqueous solution of sodium carbonate.

a. Write an appropriate chemical equation to describe the reaction between the aqueous solutions of ethanoic acid and sodium carbonate. **1 mark**

b. In the procedure that the student followed, they took 20.00 mL aliquots of ethanoic acid and neutralised it with the sodium carbonate. The average titre required 13.56 mL of 0.0846 M sodium carbonate.

i. Determine the number of mole of sodium carbonate added in the average titre. **1 mark**

ii. Determine the concentration of the ethanoic acid solution. **2 marks**

c. What mass of pure ethanoic acid would have been required to prepare 500.0 mL of solution? **1 mark**

d. Ethanoic acid is a weak acid.

i. Explain what is meant by the term "weak acid", using an appropriate chemical equation to assist. **2 marks**

ii. Explain how the pH of this solution of ethanoic acid would compare with the pH of an aqueous solution of hydrochloric acid with the same concentration. **1 mark**

Question 9 (7 marks, 9 minutes)

a. An expandable balloon is filled with 50.0 g of helium at SLC.

i. What would be the volume of the balloon? **1 mark**

ii. The balloon is released into the atmosphere and rises to an altitude where the pressure and temperature are 63000 Pa and 120 K respectively. What would be the volume of the balloon at this altitude? **1 mark**

b. The gas phase reaction between nitrogen(I) oxide and oxygen can be described by the chemical equation

$$2N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g)$$

i. What volume of oxygen gas at STP would be required to react with 2.6 L of nitrogen(I) oxide gas at the same conditions? **1 mark**

ii. What volume of $NO_2(g)$ would be formed when the appropriate amounts of the gases were reacted at STP? **1 mark**

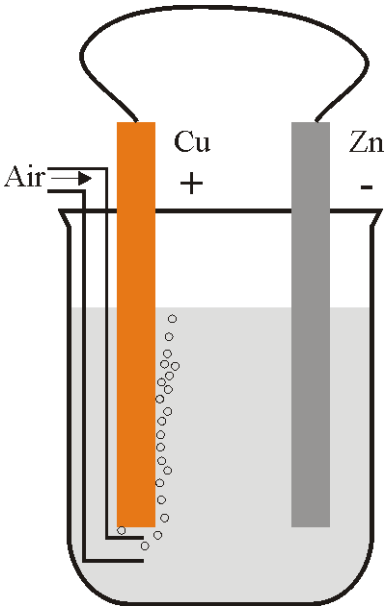
c. 100.0 mL of propane, $C_3H_8(g)$, and 800.0 mL of oxygen were placed in a piston at SLC. The mixture was ignited with a spark and the piston returned to SLC.

i. Write an appropriate chemical equation for the combustion of propane. **1 mark**

ii. Calculate the volume of gases inside the piston following the combustion reaction and after it had been returned to SLC. **2 marks**

Question 10 (8 marks, 10 minutes)

a. The apparatus shown in the diagram was set up to investigate the reactions that would occur when copper metal was attached to a piece of zinc in a moist environment. After a period of time a white solid was observed on the bottom of the beaker under the zinc rod.



i. Write an appropriate chemical half equation for the reaction occurring at the zinc rod. **1 mark**

ii. What electrochemical process is occurring at the copper rod? **1 mark**

iii. Write an appropriate chemical half equation for the reaction occurring at the copper rod. **1 mark**

iv. Write a balanced chemical equation for the overall reaction that is occurring. **1 mark**

v. What would be the white solid formed under the zinc rod? **1 mark**

b. Write an appropriate chemical equation for the reaction that would occur when a clean piece of aluminium foil is placed in an aqueous solution of lead(II) nitrate. **1 mark**

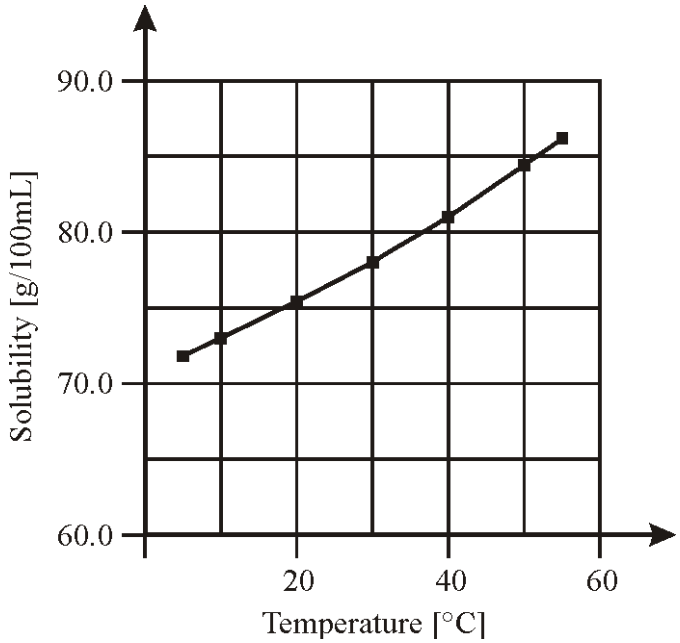
c. Steel metal food cans are coated with a thin layer of tin metal resulting in the commonly used term for them as 'tin cans'.

i. How does the tin protect the steel from corroding? **1 mark**

ii. What would happen if the tin layer were broken on the surface of the can? **1 mark**

Question 11 (6 marks, 7 minutes)

a. The diagram below shows part of the solubility curve for ammonium sulfate, $(NH_4)_2SO_4$.



A student placed 205 g of solid ammonium sulfate in a beaker and added 250 mL of deionised water. To what temperature would the student have to heat the mixture in order to produce a saturated solution? **2 marks**

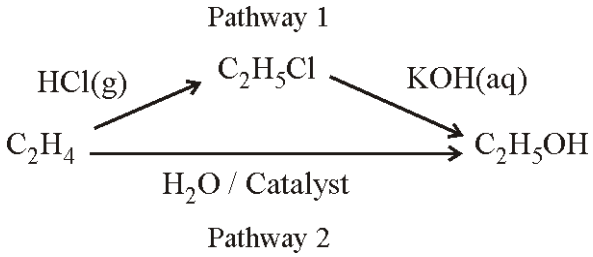
b. When aqueous solutions of barium nitrate and chromium(III) sulfate are mixed, a white precipitate is formed. Write an appropriate chemical equation for the reaction that has occurred. **1 mark**

c. Most town water supplies are chlorinated at a treatment plant prior to distribution to homes. Why is the water chlorinated? **1 mark**

d. Deionised water is regularly used in laboratories to prepare solutions and wash equipment. Explain what occurs when a sample of water is deionised. **2 marks**

Question 12 (5 marks, 6 minutes)

a. Two pathways for the industrial production of ethanol from ethene are shown in the diagram below.



Compared with Pathway 1, what are two principles of Green Chemistry that are followed in Pathway 2? **2 marks**

b. **i.** What is the main process by which carbon dioxide is removed from the atmosphere? **1 mark**

ii. What is one way that nitrogen is removed from the atmosphere and added to the soil by natural processes? **1 mark**

c. What is one gas that can be in the atmosphere that leads to the formation of acid rain? **1 mark**

Question 13 (8 marks, 10 minutes)
An organic compound containing carbon, hydrogen and oxygen when burnt in oxygen will produce carbon dioxide and water.

a. When a 1.074 g sample of this compound was burnt, it produced 1.074 g of water and 1.105 L of dry carbon dioxide at 106 kPa and 22.3 °C.

i. Determine the percentage by mass of carbon in the compound. **2 marks**

ii. Determine the percentage by mass of hydrogen in the compound. **2 marks**

iii. Determine the percentage by mass of oxygen in the compound. **1 mark**

iv. Determine the empirical formula for this compound. **1 mark**

b. When a 1.074 g sample of this compound was vaporised, it occupied a volume of 0.442 L at 106 kPa and 200 °C.

i. Determine the molar mass of this compound. **1 mark**

ii. Determine the molecular formula for the compound. **1 mark**

End of Section B

End of Trial Exam

Suggested Answers

VCE Chemistry 2013 Year 11 Trial Exam Unit 1/2

SECTION A – Multiple Choice Answers

(1 mark per question)

Q1 **A** The relative atomic mass for boron can be obtained from the Periodic Table (Table 1: VCE Chemistry Data Book).
The relative atomic mass is the abundance weighted average of the isotopic masses for the element. Taking the isotopic masses for the two isotopes, ^{10}B and ^{11}B as 10 and 11 respectively and allowing the abundance of the lighter isotope to be x % then
$A_r = 10\times(x/100) + 11\times((100-x)/100) = 10.8$
$10x + 1100 – 11x = 1080$
Solve this relationship for x
$x = 20$
The abundance of the lighter isotope would be **about 20 %**

Q2 **C** Both **phosphorous and bismuth are in Group 15** of the Periodic Table.
Moving down a group in the Periodic Table the **metallic character of the elements increases**.
The electronegativity decreases moving down a group because the valence shell is 'further' from the nucleus.
The atomic radius increases because electrons are occupying more shells in their ground state.

Q3 **A** The percentage lithium will be the least when the contribution of the other elements to the molar mass is the greatest per lithium.
A: **Lithium nitrate, $LiNO_3$**. $M = 6.9 + (14.0 + 3\times16.0) = 6.9 + \mathbf{62.0}$
$\%(Li) = (6.9/68.9) \times (100/1) = 10.0\ \%$
B: Lithium hydroxide, LiOH. $M = 6.9 + (16.0 + 1.0) = 6.9 + 17.0$
$\%(Li) = (6.9/23.9) \times (100/1) = 28.9\ \%$
C: Lithium sulfate, Li_2SO_4. $M = 2\times6.9 + (32.1 + 4\times16.0)$
$2\times6.9 + 96.1 \Rightarrow 6.9 + 48.05$
$\%(Li) = ((2\times6.9)/109.9) \times (100/1) = 12.6\ \%$
D: Lithium chloride, LiCl. $M = 6.9 + 35.5$
$\%(Li) = (6.9/42.4) \times (100/1) = 16.3\ \%$

Q4 **B** The ion has a 2- charge therefore there will be two more electrons present in the ion than there are protons.
Number of protons = 36 – 2 = 34
Number of neutrons = 42
Mass Number = Number of protons + neutrons = 34 + 42 = **76**

Q5 **D** The subshells for ground state atoms fill in the order:
1s 2s 2p 3s 3p 4s 3d 4p …….
The number of electrons in full s, p and d subshells are 2, 6 and 10 respectively.
The only response that fulfils these criteria is D.
Atoms with half and full d-subshells have energies lower than that for a full s-subshell and 4 or 9 electrons in a d subshell. Therefore the ground state electronic configurations for chromium and copper (in the first transition metal series) are $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5 4s^1$ *and* $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ *respectively.*

Q6 **B** $n(O_2) = m/M = 8.0/32.0 = 0.25$ mol
$n(O) = 2 \times n(O_2) = 2 \times 0.25 =$ **0.50 mol**
A: H atoms: $n(H_2) = 1.0/2.0 = 0.5$ mol $\Rightarrow$ $n(H) = 1.0$ mol
B: H_2O molecules: $n(H_2O) = 9.0/18.0 =$ **0.50 mol**
C: Atoms in CH_4: $n(CH_4) = 4.0/16.0 = 0.25$ mol
$\Rightarrow n(\text{atoms}) = 5 \times 0.25 = 1.25$ mol
D: CO_2 molecules: $n(CO_2) = 11.0/44.0 = 0.25$ mol

Q7 **D** The formula for the oxide is XO_2.
$m(O) = 3.579 - 2.146 = 1.433$ g
$n(O) = m/M = 1.433/16.0 = 8.96 \times 10^{-2}$ mol
$n(X) = \frac{1}{2} n(O) = \frac{1}{2} \times 8.96 \times 10^{-2} = 4.48 \times 10^{-2}$ mol
$M(X) = m/n = 2.146/4.48 \times 10^{-2} = 47.9$ g mol^{-1}
From the Periodic Table (Table 1: VCE Chemistry Data Book), the element with the relative closest to this value is **titanium**.
Alternative Solution:
%(O) = 1.433/3.579 × 100/1 = 40.0 %
%(X) = 100 – 40.0 = 60.0 %
The percentage oxygen results from two oxygen atoms and contributes 32 to the molecular mass, therefore the relative atomic mass for X is
$A_r(X) = (60/40) \times 32 = 48$

Q8 **C** The atomic number for germanium is 32.

A: Atoms with 41 neutrons would have a mass of 32+41 = 73. A peak is present in the mass spectrum at 73 therefore these atoms are present in the sample.

B: The height of the peak in the mass spectrum for ^{72}Ge is not twice that of the peak for ^{70}Ge.

C. Atoms with 43 neutrons would have a mass of 32+43 = **75**. **No peak is present in the mass spectrum at 75** therefore these atoms are not present in the sample.

D: The sum of all of the individual abundances of the isotopes in the sample adds up to 100 %. ^{74}Ge is the most abundant isotope in the sample.

Q9 **A**

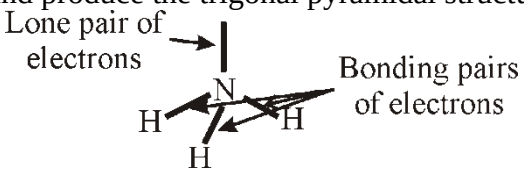
$M(BaO) = 137.3 + 16.0 = 153.3 \text{ g mol}^{-1}$
$\%(O) = (16.0/153.3) \times (100/1) = 10.44\ \%$
$m(O) = m(BaO) \times \%(O) = 5.342 \times (10.44/100) =$ **0.558 g**
Alternative solution:
$n(BaO) = m/M = 5.342 / 153.3 = 3.48 \times 10^{-2}$ mol
$n(O) = n(BaO) = 3.48 \times 10^{-2}$ mol
$m(O) = n \times M = 3.48 \times 10^{-2} \times 16.0 = 0.558$ g
or based on the chemical equation for the reaction

$$2Ba(s) + O_2(g) \rightarrow 2BaO(s)$$

$n(O_2) = ½ n(BaO) = ½ \times 3.48 \times 10^{-2}$ mol $= 1.74 \times 10^{-2}$ mol
$m(O_2) = n \times M = 1.74 \times 10^{-2} \times 32.0 = 0.558$ g

Q10 **D**

The structure of ammonia, NH_3, involves three single covalent bonds between the nitrogen and hydrogen atoms and a lone pair of electrons on the nitrogen. This results in four zones of electrical charge around the nitrogen which repel each other and produce the trigonal pyramidal structure of ammonia.



Q11 **B**

The longest carbon-carbon atom chain containing the carbon-carbon double bond has four carbons, therefore **butene**.
The carbon-carbon double bond is between the second and third carbon atom in the chain, therefore **but-2-ene**.
A methyl group is attached to one of the carbon atoms joined by the double carbon-carbon bond, therefore either 2-methyl or 3-methyl. The lower numbering is the one used in the systematic name, therefore **2-methylbut-2-ene**.

Q12 **C**

Sodium chloride, NaCl, is soluble whereas silver chloride, AgCl, is insoluble in water. Both compounds consist of a lattice of singly charged positive and negative ions so the attractive electrostatic forces between the ions should be comparable. Therefore the ionic bonding model has a limitation in explaining this phenomenon.

Q13 **B**

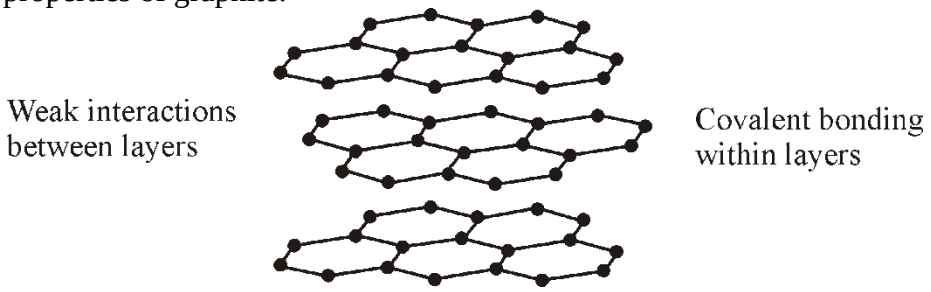
Since the polymeric material is rigid and does not readily soften when heated then the polymer chains cannot readily slide over each other. For this to occur there must be significant cross-linking between the chains.
Cross linkages involve covalent bonds which are not readily broken and hold the polymer chains in place.

Q14 **B**

The complete combustion of a hydrocarbon yields **carbon dioxide and water**. For example the complete combustion of propane can be described by the chemical equation

$$C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$$

Q15 A Graphite has a layer network structure, where the carbon atoms within the layer are joined together by covalent bonds. The interactions between the layers involve weak bonding and this accounts for the observed physical properties of graphite.



Q16 B The amide ion, NH_2^-, is a base therefore it will accept a hydrogen ion, H^+, to form its conjugate acid, which is ammonia, **NH_3**.
This could be represented by either of the chemical equations

$$NH_2^-(aq) + H_3O^+(aq) \rightleftharpoons NH_3(aq) + H_2O(l)$$

$$NH_2^-(aq) + H_2O(l) \rightleftharpoons NH_3(aq) + OH^-(aq)$$

Q17 D Redox reactions involve the transfer of electrons from the reductant to the oxidant. Reduction is the gain in electrons and the **reductant brings this process about**, therefore **the reductant donates electrons**. Since oxidation is the loss of electrons (OILRIG) then the **reductant is oxidised** in the redox process.
The reaction between zinc metal and an aqueous solution of copper(II) ions, $Cu^{2+}(aq)$, can be represented by the chemical equation

$$Cu^{2+}(aq) + Zn(s) \rightarrow Cu(s) + Zn^{2+}(aq)$$

In this reaction the zinc metal is losing electrons to the copper(II) ions, therefore it is the reductant and in the process it is oxidised to the zinc(II) ion.

Q18 A In 50.0 mL:
$n(OH^-) = n(NaOH) = c \times V = 1.0 \times (50.0/1000) = 5.0 \times 10^{-1}$ mol
This is amount of hydroxide ions are present in 5.0 L after dilution
$c(OH^-) = [OH^-] = n/V = 5.0 \times 10^{-2} / 5.0 = 1.0 \times 10^{-2}$ M
Alternative solution: since the amount of hydroxide ions is the same in both the original and diluted solution,
$1.0 \times (50.0/1000) = c(OH^-) \times 5.0$
$c(OH^-) = 5.0 \times 10^{-2} / 5.0 = 1.0 \times 10^{-2}$ M
From the table of physical constants, Table 3: VCE Chemistry Data Book, the self ionisation constant for water
$K_w = [H^+][OH^-] = 1.00 \times 10^{-14}$ M^2
$[H^+](1.0 \times 10^{-2}) = 1.00 \times 10^{-14}$
$[H^+] = 1.00 \times 10^{-14} / (1.0 \times 10^{-2}) = 1.0 \times 10^{-12}$ M
$pH = -\log_{10}[H^+] = -\log_{10}(1.0 \times 10^{-12})$ = **12**

Q19 D An aqueous solution of iron(II) sulfate contains iron(II), $Fe^{2+}(aq)$, and sulfate, $SO_4^{2-}(aq)$, ions. All common **nitrate, Group 1 and ammonium compounds are soluble in water**, therefore adding an aqueous solution of **ammonium nitrate** will **not** produce a precipitate.
The other three responses will produce precipitates as described by the chemical equations:

A: $Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

B: $Fe^{2+}(aq) + 2OH^{-}(aq) \rightarrow Fe(OH)_2(s)$

C: $Fe^{2+}(aq) + CO_3^{2-}(aq) \rightarrow FeCO_3(s)$

Q20 C $M((NH_4)_2SO_4) = 2\times14.0 + 8\times1.0 + 32.1 + 4\times16.0 = 132.1 \text{ g mol}^{-1}$
$n((NH_4)_2SO_4) = m/M = 7.932 / 132.1 = 6.00\times10^{-2} \text{ mol}$
$n(NH_4^+) = 2n((NH_4)_2SO_4) = 2 \times 6.00\times10^{-2} = 1.20\times10^{-1} \text{ mol}$
$c(NH_4^+) = n/V = 1.20\times10^{-1} / (250.0/1000) =$ **0.48 M**

Q21 D Sodium chloride is an ionic solid, therefore when it dissolves in water it will dissociate into its ions, as described by the chemical equation

$$NaCl(s) \xrightarrow{H_2O(l)} Na^+(aq) + Cl^-(aq)$$

Water is a polar molecule, therefore it will form ion-dipole bonds with the sodium and chloride ions.

Q22 B The reaction between acids and carbonates produces a salt of the acid, carbon dioxide and water.
Nitric acid solution, $HNO_3(aq)$, will yield the corresponding magnesium nitrate, $Mg(NO_3)_2$, which like all common nitrates is soluble in water.

$$MgCO_3(s) + 2HNO_3(aq) \rightarrow Mg(NO_3)_2(aq) + H_2O(l) + CO_2(g)$$

Q23 C The conditions are STP.
From the table of physical constants Table 3: VCE Chemistry Data Book
$V_m(STP) = 22.4 \text{ L mol}^{-1}$
$n(gas) = V/V_m = (450/1000) / 22.4 = 2.00\times10^{-2} \text{ mol}$
$M(gas) = m/n = 1.287 / 2.00\times10^{-2} = 64.1 \text{ g mol}^{-1}$
$M(Cl_2) = 2\times35.5 = 70.0 \text{ g mol}^{-1}$
$M(C_5H_8) = 5\times12.0 + 8\times1.0 = 68.0 \text{ g mol}^{-1}$
$M(SO_2) = 32.1 + 2\times16.0 =$ **64.1 g mol^{-1}**
$M(ClO_2) = 35.5 + 2\times16.0 = 67.5 \text{ g mol}^{-1}$
Therefore the gas is sulfur dioxide, **SO_2**.

Q24 A The chemical equation for the reaction is

$$2KClO_3(s) \xrightarrow{MnO_2(s)} 2KCl(s) + 3O_2(g)$$

$M(KCl) = 39.1 + 35.5 = 74.6 \text{ g mol}^{-1}$
$n(KCl) = m/M = 14.618/74.6 = 1.95\times10^{-1} \text{ mol}$
$n(O_2) = {}^3/_2 n(KCl) = {}^3/_2 \times 1.95\times10^{-1} = 2.94\times10^{-1} \text{ mol}$
From the table of physical constants Table 3: VCE Chemistry Data Book
$V_m(SLC) = 24.5 \text{ L mol}^{-1}$
$V(O_2) = n\times V_m = 2.94\times10^{-1} \times 24.5 =$ **7.20 L**

Q25 C The use of fossil fuels in vehicles leads to the emission of carbon dioxide, unburnt hydrocarbons and nitrogen oxides into the atmosphere. The level of these gases in the atmosphere will be most affected by the use of fossil fuels. The combustion of these fuels consumes oxygen, however the concentration of oxygen is least affected because it makes up a much larger part of the atmosphere than the other gases.

Q26 B The conditions are not standard, therefore the general gas equation has to be used.

$PV = nRT$

$V = 55.7$ L $P = 18100$ kPa $T = 15 + 273 = 288$ K

$$n(N_2) = \frac{PV}{RT} = \frac{18100 \times 55.7}{8.31 \times 288} = 421 \text{ mol}$$

$M(N_2) = 2 \times 14.0 = 28.0 \text{ g mol}^{-1}$

$m(N_2) = n \times M = 421 \times 28.0 = 11800 \text{ g} =$ **11.8 kg.**

Q27 D The chemical equation describing the reaction is

$$2N_2O(g) + 3O_2(g) \rightarrow 4NO_2(g)$$

Since the conditions for the two gases are the same then the volume ratio is equal to the molar ratio of the reactants.

$V(O_2) = 364$ mL

$V(N_2O) = {}^2/_3 V(O_2) = {}^2/_3 \times 364 =$ **243 mL**

Q28 B In the laboratory, a sample of oxygen gas is most conveniently prepared by reacting an aqueous solution of hydrogen peroxide, $H_2O_2(aq)$, with manganese(IV) oxide, $MnO_2(s)$. In this reaction, the manganese(IV) oxide acts as a catalyst and the hydrogen peroxide acts as both the oxidant and reductant.

Reduction reaction: $H_2O_2(aq) + 2H^+(aq) + 2e^- \rightarrow 2H_2O(l)$

Oxidation reaction: $H_2O_2(aq) \rightarrow O_2(g) + 2H^+(aq) + 2e^-$

Overall reaction: $2H_2O_2(aq) \rightarrow O_2(g) + 2H_2O(l)$

The fractional distillation of liquid air is how oxygen is produced on the industrial scale.

Q29 A Photosynthesis is the process that plants use to synthesise glucose from carbon dioxide and water using light and with the aid of chlorophyll. Therefore it is the main process that removes carbon from the atmosphere.

The photosynthesis process can be represented by the chemical equation

$$6CO_2(g) + 6H_2O(l) \xrightarrow[\text{light}]{\text{chlorophyll}} C_6H_{12}O_6(aq) + 6O_2(g)$$

Q30 C The water has formed droplets on the surface, therefore the forces of attraction between the water molecules are greater than those between the water molecules and the particles on the surface. In this case the water has not wet the surface.

SECTION B – Short Answer (Answers)

Question 1 (8 marks, 10 minutes)

a. **i.** The first ionisation energy of an element is the amount of **energy required to remove one electron** from an atom of the element **(1 mark)**. The electron will be removed from the valence, or outer, shell. This energy can be quoted in kJ mol^{-1} or electron volts (eV). The process can be represented by the chemical equation.

$$E(g) \rightarrow E^{+}(g) + e^{-}$$

ii. The trend in the diagram shows that the first ionisation energy for the elements decreases moving down the group. Moving down the group the valence, or outer shell, electrons are in a higher shell number, therefore further from the nucleus of the atom **(1 mark)**.

Since all elements are in the same group then the valence electrons will be attracted by the same effective nuclear charge. In the case of Group 2 elements this is +2. However because the effective distance between the nucleus and the valence shell increases moving down a group, the force of attraction decreases and the energy required to remove an electron from this shell will decrease **(1 mark)**.

iii. Both elements are in the same period so the electron removed will be in the same shell. Sodium is in Group 1, therefore the valence electron will experience an attraction with an effective nuclear charge of +1. This will result in a lower attractive force and hence the first ionisation energy will be lower than that for magnesium **(1 mark)**. (The first ionisation energy for sodium is 502 kJ mol^{-1}.)

b. **i.** The electronegativity of an element is the ability of the atom to attract an electron when bonded to another element **(1 mark)**.

ii. Moving across a period in the Periodic Table, the effective nuclear charge experienced by the valence shell increases from +1 to +7. Therefore elements to the right in a period will have higher electronegativities than those elements on the left of the period **(1 mark)**. (The electronegativity for lithium, nitrogen and fluorine are 0.98, 3.04 and 3.98 respectively.)

c. Arsenic is in Group 15 and Period 4 of the Periodic Table. Moving across a period the non-metallic character of the element increases, so comparing arsenic with nitrogen, it would be expected to have a non-metallic character **(1 mark)**. Moving down a group within the Periodic Table, the metallic character of the elements increases, therefore arsenic would have a more metallic character than nitrogen **(1 mark)**. Arsenic is one of the elements which displays both metallic and non-metallic characteristics.

Question 2 (8 marks, 10 minutes)

a. **i.** From the percentage by mass composition determine the mol ratio of the elements assuming 100 g of compound.

n(C) : n(H) : n(N) = m(C)/M(C) : m(H)/M(H) : m(N)/M(N)
= 54.5/12.0 : 13.7/1.0 : 31.8/14.0
= 4.54 : 13.7 : 2.27 **(1 mark)**

Divide the three values by the smallest value
= 2 : 6 : 1

C_2H_6N (1 mark)

ii. $M(C_2H_6N) = 2\times12.0 + 6\times1.0 + 14.0 = 44.0$ g mol^{-1}

The molecular formula is a whole number multiple of the empirical formula, $(C_2H_6N)_n$.

$n = 88.0/44.0 = 2$

$C_4H_{12}N_2$ (1 mark)

b. **i.** $MnSO_4 \cdot 7H_2O(s) \rightarrow MnSO_4(s) + 7H_2O(g)$ **(1 mark)**

ii. $M(H_2O) = 2\times1.0 + 16.0 = 18.0$ g mol^{-1}

$M(MnSO_4 \cdot 7H_2O) = 54.9 + 32.1 + 4\times16.0 + 7\times18.0 = 277.0$ g mol^{-1} **(1 mark)**

The decrease in mass will be the removal of the waters of crystallisation.

$\%(H_2O) = ((7\times18.0)/277.0) \times (100/1) =$ **45.5 % (1 mark)**

c. Let the abundance of the heavier isotope be x %, therefore the abundance of the lighter isotope will be (100 – x)%.

The relative atomic mass of silver is 107.9 and this is the weighted average of the isotopic masses.

$106.91\times((100-x)/100) + 108.90\times(x/100) = 107.9$ **(1 mark)**

Multiply both sides of the equation and expand.

$10691 - 106.91x + 108.90x = 10790$

Collect like terms.

$1.99x = 99$

$x = 49.7$

The abundance of the heavier isotope is **49.7 % (1 mark)**

Question 3 (6 marks, 7 minutes)

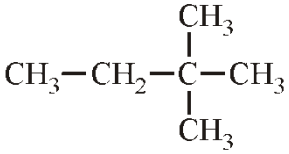
a. **i.** 2,2-dimethyl**butane** – longest carbon-carbon backbone contains four carbon atoms joined by single bonds only.

2,2-dimethylbutane – two methyl groups, $-CH_3$, both attached to the second carbon atom in the backbone. **(1 mark)**

ii. 2-methylpent-2-ene – longest carbon-carbon backbone contains five carbon atoms with a carbon-carbon double bond between carbon atoms 2 and 3.

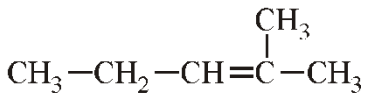
2-methylpent-2-ene – a methyl group, $-CH_3$, attached to the second carbon atom in the backbone and the one with the double bond. **(1 mark)**

i.



2,2-dimethylbutane

ii.



2-methylpent-2-ene

b.

Characteristic	Affect of Isomers
i. Molecular formula	Hydrocarbon isomers have the same molecular formulae. **(1 mark)**
ii. Molecular structure	Hydrocarbon isomers have different molecular structures. **(1 mark)** For example: butane and 2-methylpropane both have the same molecular formulae but different structures, $CH_3CH_2CH_2CH_3$ and $CH_3CH(CH_3)_2$ respectively.
iii. Chemical properties	Since the types of bonding within isomers will be the same then the chemical properties of the isomers will be similar. **(1 mark)**
iv. Physical properties	As the structures of the isomers are different then there will be some difference in how the molecules will interact with each other. This will result in small differences in the physical properties of the isomers. **(1 mark)** For example the boiling temperatures for butane and 2-methylpropane are -0.5 °C and 27.9 °C respectively

Question 4 (8 marks, 10 minutes)

a. The maximum number of electrons that can occupy s, p and d sub-shells are 2, 6 and 10 respectively.
When an atom forms an ion the electrons are either added or removed from the valence, or outer, shell.
The sub-shells fill in the order: 1s, 2s, 2p, 3s, 3p, 4s, 3d, 4p …….

i. An iron(II) ion, Fe^{2+}. Z(Fe) = 26 Number of electrons = 24
The 4s sub-shell is the outer or valence shell, therefore the two electrons that would be present in the ground state electronic configuration of an iron atom will be removed from this sub-shell when the iron(II) ion forms.
$1s^2 2s^2 2p^6 3s^2 3p^6 3d^6$ (1 mark)

ii. A silicon atom, Si. Z(Si) = 14 Number of electrons = 14
$1s^2 2s^2 2p^6 3s^2 3p^2$ (1 mark)

b. The atomic number is the number of protons.
The mass number is the number of protons plus neutrons.

i. Number of protons = 150 – 88 = 62 therefore Sm
$^{150}_{62}Sm$ **(1 mark)**

ii. Mass number = 28 + 33 = 61
Charge = 28 – 25 = +3
$^{61}_{28}Ni^{3+}$ **(1 mark)**

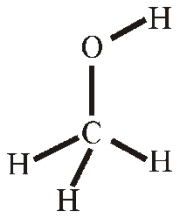
c. James Chadwick discovered the neutron in 1932 as a subatomic particle without a charge and a mass approximately equal to that of a proton **(1 mark)**. From this discovery, Chadwick was then able to explain the existence of isotopes, atoms of the same element with different masses **(1 mark)**.

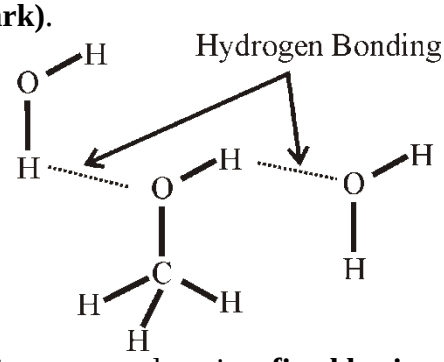
d. When an atom is heated, it absorbs energy and in the process electrons are excited to higher energy levels **(1 mark)**. The electrons then relax, or fall, to lower energy levels and in the process emit light with a quanta corresponding to the difference in energy between the two energy levels **(1 mark)**. The light emitted is characteristic of the element, as the energy levels are determined by the element's electronic structure.

Question 5 (7 marks, 9 minutes)

a. **i.** Methanol is a molecule therefore within the molecule there will be **covalent molecular bonds** between the carbon, hydrogen and oxygen atoms, as shown in the diagram below **(1 mark)**.

ii. Both water and methanol are **polar molecules**. Therefore the interactions between these two molecules will **include dispersion forces, dipole-dipole interactions and hydrogen bonding**. The **latter of these will be the strongest interaction (1 mark)**.

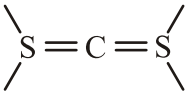


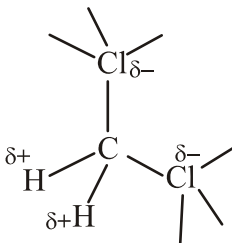


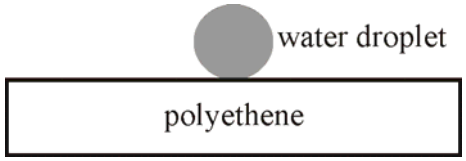
b. In the **solid state** the ions in the ionic compound are in a **fixed lattice and cannot move** about freely whereas in the **molten and aqueous phases,** the ions are **free to move and can therefore carry an electric current (1 mark)**.

c. **Carbon disulfide** is a symmetrical molecule and even though the C=S bond is polarised due to the electronegativity differences between carbon and sulfur, the molecule has **no permanent dipole**. **Dichloromethane has a permanent dipole** that results because of the electronegativity differences between chlorine, carbon and hydrogen.

[Mark allocation: 1 mark for correct structure <u>and</u> determination of polarity. Total marks allocated = 2 marks]

i. 

ii. 

d. **i.** 

(1 mark)

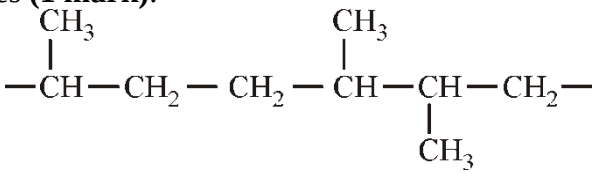
ii. The polyethene surface will be non-polar and hydrophobic therefore the water, which is polar, will not wet the surface and the droplet will not spread out **(1 mark)**. The bonding interactions between the water molecules are stronger than any bonding interactions between the water molecules and the polyethene molecules on the surface.

Question 6 (5 marks, 6 minutes)

a. **i.** The presence of bulky groups attached to the polymer chain **will not allow the chains to pack together as tightly** if they were not present. This will result in a **lower polymer density (1 mark)**.

ii. The bulky groups attached to the polymer chains will make it **more difficult for the chains to move over each other** and this will make the polymers **more brittle (1 mark)**.

b. The diagram must show at least three repeating units, single bonds between the carbon atoms in the polymer chain and methyl groups, $-CH_3$, attached to the chain in appropriate places **(1 mark)**.



c. A copolymer is a **polymer produced from two or more different monomers (1 mark)**.

Copolymers are used in some applications because they often have properties that are better than those of polymers made from the individual monomers **(1 mark)**.

Question 7 (8 marks, 10 minutes)

a. **i.** Increasing the temperature of a gas increases the average speed of the particles therefore at a near constant pressure the gas expands to occupy a larger volume. This lowers the density of the gas in that region because there are fewer particles, hence the hot gas will rise **(1 mark)**.

ii. Gas particles at a constant temperature will have the same average speed. If the volume that these particles occupy is decreased, then there will be more frequent collisions between the particles and the walls of the containing vessel. The pressure reflects the rate of collisions between particles and the walls of the containing vessel, hence the pressure increases **(1 mark)**.

iii. The number of collisions between the particles and the containing vessel walls for a given gas depends on the amount of gas present in the container and the temperature. In a mixture of gases, each gas will therefore exert a pressure, referred to as the *partial pressure*. The total pressure of the gas mixture will be the total number of collisions between the vessel walls and the particles. Consequently the total pressure will be the sum of the partial pressures **(1 mark)**.

iv. When the container of the odorous gas is opened in one corner of the room the gas particles can move from the container and mix with the gas in the room. Since the gas particles are free to move within the room the smell will spread throughout the room **(1 mark)**.

b. **i.** The reactants used to produce carbon dioxide in the laboratory are an appropriate acid and a carbonate or a hydrogen carbonate **(1 mark)**.
Heating a solid metal carbonate, such as calcium carbonate, is a possible reaction but not the preferred one in the laboratory for preparing carbon dioxide. Group 1 carbonates do not readily decompose at temperatures available in the laboratory.

ii. Possible reactions include: **(1 mark)**

Reactants: Calcium carbonate (limestone, marble) and hydrochloric acid.

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

Reactants: Solid sodium carbonate and hydrochloric acid.

$$Na_2CO_3(s) + 2HCl(aq) \rightarrow 2NaCl(aq) + H_2O(l) + CO_2(g)$$

Reactants: Solid sodium hydrogen carbonate and hydrochloric acid.

$$NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + H_2O(l) + CO_2(g)$$

General ionic chemical equation:

$$CO_3^{2-}(s) + 2H^+(aq) \rightarrow H_2O(l) + CO_2(g)$$

iii. **Carbon dioxide** is **slightly soluble in water** and will react to form a solution of **carbonic acid**. This is a **weak acid** and will partially ionise to release **H^+(aq) ions** that cause the indicator to change colour **(1 mark)**.

$$CO_2(g) + H_2O(l) \rightleftharpoons H_2CO_3(aq)$$

$$H_2CO_3(aq) + H_2O(l) \rightleftharpoons HCO_3^-(aq) + H_3O^+(aq)$$ **(1 mark)**

Question 8 (8 marks, 10 minutes)

a. Either a full or ionic equation would be appropriate **(1 mark)**.

$$2CH_3COOH(aq) + Na_2CO_3(aq) \rightarrow 2NaCH_3COO(aq) + H_2O(l) + CO_2(g)$$

$$2H^+(aq) + CO_3^{2-}(aq) \rightarrow H_2O(l) + CO_2(g)$$

b. **i.** $n(Na_2CO_3) = c \times V = 0.0846 \times (13.56/1000) =$ **1.15×10^{-3} mol (1 mark)**

ii. $n(CH_3COOH) = 2n(Na_2CO_3) = 2 \times 1.15 \times 10^{-3} = 2.30 \times 10^{-3}$ mol **(1 mark)**

$c(CH_3COOH) = n/V = 2.30 \times 10^{-3} / (20.00/1000) =$ **0.115 M (1 mark)**

c. $n(CH_3COOH) = c \times V = 0.115 \times (500.0/1000) = 5.74 \times 10^{-2}$ mol

$M(CH_3COOH) = 2 \times 12.0 + 4 \times 1.0 + 2 \times 16.0 = 60.0$ g mol^{-1}

$m(CH_3COOH) = n \times M = 5.74 \times 10^{-2} \times 60.0 =$ **3.44 g (1 mark)**

d. **i.** A **weak acid is an acid that does not completely ionise** when dissolved in water. Therefore the solution contains a significant amount of unionised molecules **(1 mark).**

$$CH_3COOH(aq) + H_2O(l) \rightleftharpoons CH_3COO^-(aq) + H_3O^+(aq)$$ **(1 mark)**

ii. Since the ethanoic acid has not completely ionised then the concentration of the H^+(aq) ion will be significantly less than that of the acid. Hydrochloric acid is a strong acid and is completely ionised, therefore the concentration of the H^+(aq) is the same as the acid. Comparing equal concentration solutions then the **concentration of the H^+(aq) ion in the ethanoic acid solution will be lower and this will have a higher pH (1 mark).**

Question 9 (7 marks, 9 minutes)

a. **i.** $n(He) = m/M = 50.0 / 4.0 = 12.5$ mol

$V(He) = n \times V_m = 12.5 \times 24.5 =$ **306 L (1 mark)**

ii. Since the amount of helium is the same then the combined gas equation can be used.

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$P_1 = 101.3$ kPa $\quad P_2 = 63000$ Pa $= 63.0$ kPa

$T_1 = 298$ K (25 °C) $\quad T_2 = 120$ K

$V_1 = 306$ L

$$V_2 = \frac{P_1V_1T_2}{T_1P_2} = \frac{101.3 \times 306 \times 120}{298 \times 63.0} =$$ **198 L (1 mark)**

b. Since all conditions are at STP then the volume ratios are equal to the mol ratios.

i. $n(O_2) = {}^3/_2 n(N_2O)$

$V(O_2) = {}^3/_2 V(N_2O) = {}^3/_2 \times 2.6 =$ **3.9 L (1 mark)**

ii. $V(NO_2) = 2V(N_2O) = 2 \times 2.6 =$ **5.2 L (1 mark)**

c. **i.** The complete combustion of a hydrocarbon produces carbon dioxide and water.

1. Write down the reactants and products of the reaction.
   $C_3H_8(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
2. Balance the number of carbon atoms in the chemical equation.
   $C_3H_8(g) + O_2(g) \rightarrow 3CO_2(g) + H_2O(l)$
3. Balance the number of hydrogen atoms in the chemical equation.
   $C_3H_8(g) + O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$
4. Balance the number of oxygen atoms in the chemical equation remembering that the reactant is O_2.
   Products: $3 \times 2 + 4 = 10$
   O_2 molecules required = 5
   $C_3H_8(g) + 5O_2(g) \rightarrow 3CO_2(g) + 4H_2O(l)$ **(1 mark)**

ii. From the chemical equation:

100.0 mL of propane requires 500.0 mL of oxygen, therefore the oxygen is in excess

$V(O_2, \text{excess}) = 800.0 - 500.0 = 300.0$ mL **(1 mark)**

$V(CO_2, \text{produced}) = 3V(C_3H_8) = 3 \times 100.0 = 300.0$ mL

Since the system is at SLC then water will be in its liquid state.

$V(\text{gases}) = 300.0 + 300.0 =$ **600.0 mL (1 mark)**

Question 10 (8 marks, 10 minutes)

a. **i.** Since this is the negative electrode in this galvanic process then oxidation will be occurring.

$Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$ **(1 mark)**

ii. The copper rod is positively charged therefore **reduction** will be occurring at this electrode **(1 mark)**.

iii. The oxygen in the air is being reduced.

$O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$ **(1 mark)**

iv. $2Zn(s) + O_2(g) + 2H_2O(l) \rightarrow 2Zn^{2+}(aq) + 4OH^-(aq)$ **(1 mark)**

v. **Zinc hydroxide**, $Zn(OH)_2$ **(1 mark)**

b. From the electrochemical series the appropriate chemical half-equations would be.

Reduction reaction: $Pb^{2+}(aq) + 2e^- \rightarrow Pb(s) \times 3$

Oxidation reaction: $Al(s) \rightarrow Al^{3+}(aq) + 3e^- \times 2$

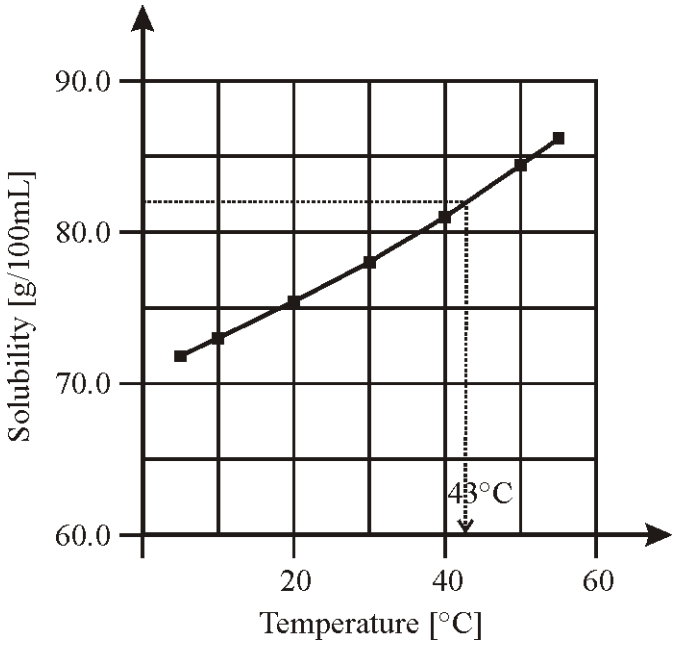
Overall reaction: $3Pb^{2+}(aq) + 2Al(s) \rightarrow 3Pb(s) + 2Al^{3+}(aq)$ **(1 mark)**

c. **i.** **Tin is less reactive** than the iron in the steel and is also considerably less reactive with the oxygen in the air due to the formation of an unreactive layer on the tin. Therefore it provides a **passive protection** of the steel **(1 mark)**.

ii. If the tin layer is broken then the iron will be exposed and it can undergo oxidation **(1 mark)**. When this occurs the steel becomes the anode and the remaining tin becomes the cathode and the can will rust.

Question 11 (6 marks, 7 minutes)

a. 205 g of solid ammonium sulfate is required to be dissolved in 250 mL of deionised water.
This would require a solubility of
(205/250) × 100
= 82 g / 100 mL **(1 mark)**.
From the solubility curve this would require heating the solution to 43 °C to prepare a saturated solution **(1 mark)**.



b. Since all common nitrate compounds are soluble then the precipitate would be barium sulfate. This is supported by the colour as chromium(III) compounds tend to be coloured because chromium is a transition metal element.
Either an ionic or full equation would be appropriate **(1 mark)**.

$3Ba(NO_3)_2(aq) + Cr_2(SO_4)_3(aq) \rightarrow 3BaSO_4(s) + 2Cr(NO_3)_3(aq)$

$Ba^{2+}(aq) + SO_4^{2-}(aq) \rightarrow BaSO_4(s)$

c. Most town water supplies are chlorinated to **destroy bacteria and prevent the transmission of waterborne diseases (1 mark)**.

d. During deionisation of water the small amounts of cations are replaced by hydrogen ions, $H^+(aq)$, and the anions are replaced by hydroxide ions, $OH^-(aq)$ **(1 mark)**. These two ions will then react to form water **(1 mark)**.

Question 12 (5 marks, 6 minutes)

a. The main Green Chemistry principle that Pathway 2 has is the maximisation of atomic economy **(1 mark)**. In Pathway 1 the potassium and chlorine atoms are by-products.
Other principles that would be acceptable: **[1 mark allocated]**
Prevention of waste.
Less hazardous chemicals used.
Use of catalysts.
Avoiding chemical derivatives, such as chloroethane in this system.

b. **i.** Photosynthesis **(1 mark)**

$$6CO_2(g) + 6H_2O(l) \rightarrow C_6H_{12}O_6(aq) + 6O_2(g)$$

ii. Possible answers include: **(1 mark)**
The action of nitrogen-fixing bacteria in the root nodules of some plants, such as the legumes, that convert nitrogen from the atmosphere into ammonium ions.
Lightning that results in the oxidation of nitrogen to form nitrogen oxides, which in turn dissolve in water to form nitrate and nitrite ions.

c. Possible answers include: **(1 mark)**
Sulfur dioxide, SO_2.
Sulfur trioxide, SO_3.
Nitrogen oxides.

Question 13 (8 marks, 10 minutes)

a. **i.** $V(CO_2) = 1.105$ L at 106 kPa and 22.3 °C.
General Gas Equation: $PV = nRT$
$T = 273 + 22.3 = 295.3$ K

$$n(CO_2) = \frac{PV}{RT} = \frac{106 \times 1.105}{8.31 \times 275.3} = 4.77\times10^{-2} \text{ mol}$$

$n(C) = n(CO_2) = 4.77\times10^{-2}$ mol **(1 mark)**
$m(C) = n\times M = 4.773\times10^{-2} \times 12.0 = 0.573$ g
%(C) = (0.573/1.074) × (100/1) = **53.3 % (1 mark)**

ii. $m(H_2O) = 1.074$ g
$n(H_2O) = m/M = 1.074 / (2\times1.0 + 16.0) = 5.97\times10^{-2}$ mol
$n(H) = 2\times n(H_2) = 2 \times 5.97\times10^{-2} = 1.19\times10^{-1}$ mol **(1 mark)**
$m(H) = n\times M = 1.19\times10^{-1} \times 1.0 = 0.119$ g
%(H) = (0.119/1.074) × (100/1) = **11.1 % (1 mark)**
Alternative solution:
m(H) = (2.0/18.0) × 1.074= 0.119 g
%(H) = (0.119/1.074) × (100/1) = **11.1 %**

iii. %(O) = 100 - %(C) - %(H)
%(O) = 100 – 53.3 – 11.1 = **35.6 % (1 mark)**

iv. Assume 100 g and determine the elemental mol ratio

$$n(C) : n(H) : n(O) = \frac{53.3}{12.0} : \frac{11.1}{1.0} : \frac{35.6}{16.0}$$
$$= 4.44 : 11.1 : 2.22$$

Divide all values by smallest number
$$= 2.0 : 5.0 : 1.0$$

C_2H_5O (1 mark)

b. **i.** V(gas) = 0.442 L at 106 kPa and 200 °C

$$n(gas) = \frac{PV}{RT} = \frac{106 \times 0.442}{8.31 \times 473} = 1.19 \times 10^{-2} \text{ mol}$$

M(gas) = m/n = 1.074 / 1.19×10^{-2} = **90.1 g mol^{-1} (1 mark)**

ii. The molecular formula is a whole number multiple of the empirical formula.
$M(C_2H_5O) = 2 \times 12.0 + 5 \times 1.0 + 16.0 = 45.0$ g mol^{-1}
M(gas) / $M(C_2H_5O)$ = 90.1 / 45.0 = 2
$(C_2H_5O)_2$ = **$C_4H_{10}O_2$ (1 mark)**

End of Suggested Answers