Periodic table

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Periodic table- Inorganic chemsitry
Booklet	Question Paper

Time Allowed: **75 minutes**

Score: **/65**

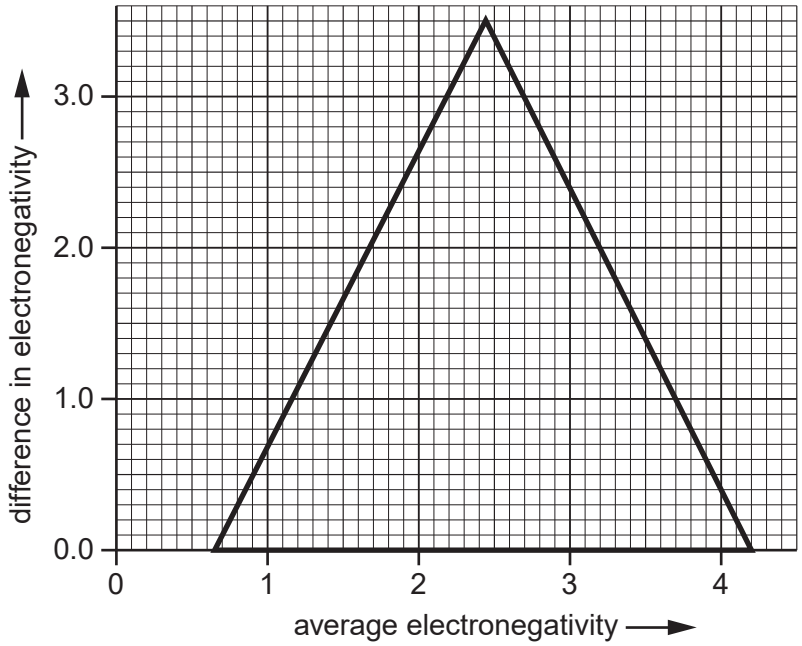
Percentage: **/100**

Grade Boundaries:

1. **(a)** Binary compounds such as cadmium sulfide, CdS, can be used to improve the efficiency of catalysts. The electronegativity values of cadmium and sulfur are shown in the table.

element	electronegativity
cadmium	1.52
sulfur	2.59

(i) Plot the position of CdS on the van Arkel triangle below.



[1]

(ii) Circle the option that best describes the bonding in CdS.

ionic **covalent** **metallic**

intermediate ionic-metallic **intermediate covalent-ionic**

intermediate covalent-metallic **intermediate covalent-ionic-metallic**

[1]

(b) Some bacteria can oxidise methane to carbon dioxide in the absence of oxygen. It has recently been reported that the mechanism involves a reaction between methane and nitrite ions in acidic conditions (reported in *Nature*, 2010).

The half-equation for the oxidation of methane is given.

$$CH_4 + 2H_2O \rightarrow CO_2 + 8H^+ + 8e^-$$

(i) Write a half-equation for the reduction of NO_2^- in acidic conditions to give N_2.

.....[2]

(ii) By combining the half-equations, or otherwise, balance the overall equation shown below.

.....CH_4 + ...NO_2^- + ...H^+ → .....CO_2 + ...N_2 + ...H_2O [1]

(iii) The oxidation of methane by nitrite ions is thermodynamically favourable but will not occur under standard laboratory conditions. Suggest briefly the role of bacteria in this reaction.

.....

.....[1]

(c) Molybdenum can form many complex oxy-ions. It has been reported that a complex molybdenum oxyanion can self-assemble to a large doughnut-shaped structure with a 3.6 nm diameter (reported in *Science*, 2010). The oxyanion unit has the formula $[Mo_{36}O_{112}(H_2O)_{16}]^{8-}$.

(i) Calculate the oxidation state of molybdenum in this oxyanion unit.

[1]

(ii) Give the empirical formula of the oxyanion unit.

..... [1]

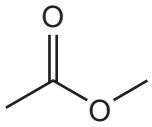
[Total: 8]

2. **(a)** Simple esters are flammable liquids. Flammability is affected by volatility. Write the following homologous series in order of boiling point, assuming molecular masses are similar.

alcohols	**alkanes**
highest boiling point	.....
↑	.....
lowest boiling point	.....

[1]

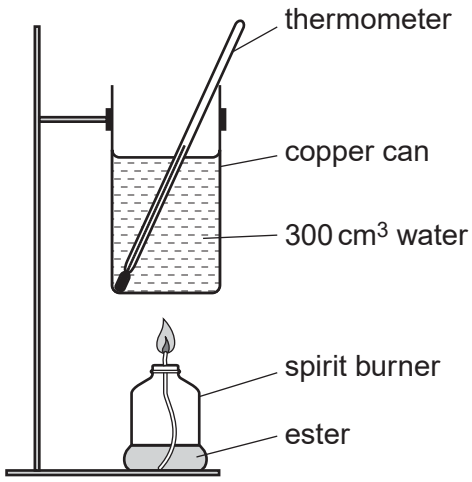
(b) The structure of methyl ethanoate, $C_3H_6O_2$, is shown below.



Write an equation for the complete combustion of methyl ethanoate.

.....[1]

(c) A student used the apparatus shown in the diagram to carry out experiments to determine the standard enthalpy change of combustion for ethyl ethanoate.



- mass of copper pot = 250 g
- volume of water = 300 cm^3

An initial experiment was carried out using methyl ethanoate. This ester was combusted in a spirit burner underneath a copper can so that the flame from the burner heated 300 cm^3 of water in the can. It was found that 0.980 g of ester was required to raise the temperature of the water in the can by 10.0 °C.

(i) Describe how this initial experiment was set up and carried out to collect the data that gave these results.

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.....[6]

(ii) Calculate the total thermal energy in kJ gained by the water and the copper can in this initial experiment. The specific heat capacities of water and copper are 4.18 and $0.384\,J\,g^{-1}\,K^{-1}$, respectively.

Take the density of water to be $1.00\,g\,cm^{-3}$. Assume that the water and copper are in thermal equilibrium with each other. Express your answer to the appropriate number of significant figures.

.....[3]

(iii) The theoretical standard enthalpy change of combustion of methyl ethanoate is –1592.1 kJ mol^{-1}. Calculate the total theoretical thermal energy in kJ released by the mass of methyl ethanoate combusted in this initial experiment.

..... kJ [2]

(iv) Heat losses are significant but can be taken into account by using the known value of $\Delta_c H^{\ominus}$ of −1592.1 kJ mol^{-1} for methyl ethanoate. A similar experiment with ethyl ethanoate produced the following results.

mass of ethyl ethanoate combusted = 0.948 g

increase in temperature of 300 cm^3 water = 11.5 °C

Calculate the most accurate possible value for the standard enthalpy change of combustion for ethyl ethanoate.

..... kJ mol^{-1} [4]

(d) Outline **four** improvements that could increase the accuracy of the raw data recorded in these experiments.

.....

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.....[4]

(e) In terms of the ease of lighting and the appearance of the flame how does methyl ethanoate compare to decyl ethanoate ($CH_3COOC_{10}H_{21}$)?

ease of lighting .....

.....

appearance of flame .....

.....

[2]

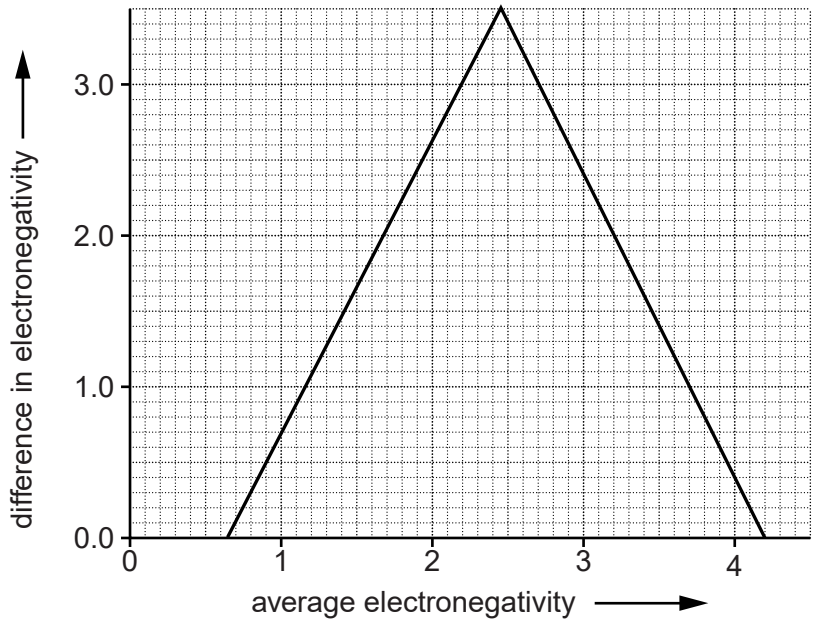
[Total: 23]

3 This question is about compounds of Group 16 elements.

(a) There has been much recent interest in the structural and electronic properties of molybdenum disulfide, MoS_2, and bismuth telluride, Bi_2Te_3. Electronegativity values for their constituent elements are shown.

element	Mo	Bi	Te	S
electronegativity	1.47	2.01	2.16	2.59

(i) Plot and label the points for MoS_2 and Bi_2Te_3 on the van Arkel diagram.



[1]

(ii) Circle the option that **best** describes the bonding in Bi_2Te_3.

intermediate covalent-metallic **intermediate ionic-metallic**

intermediate covalent-ionic **intermediate covalent-ionic-metallic**

[1]

(iii) Circle the option that **best** describes the bonding in MoS_2.

more covalent than Bi_2Te_3 **more ionic than Bi_2Te_3**

less covalent than Bi_2Te_3 **less ionic than Bi_2Te_3**

[1]

(b) **(i)** 'Fool's gold' is iron disulfide, FeS_2. The S atoms exist as an ion containing an S−S covalent bond. The iron ion exhibits an oxidation number of +2.

Draw a dot-cross diagram of the sulfur-containing ion in FeS_2, indicating the charge(s).

[3]

(ii) There are no S−S bonds in MoS_2.

What is the oxidation number of molybdenum in MoS_2?

oxidation number ..... [1]

(c) Sulfur can react with hot aqueous sodium sulfide, Na_2S, to form a yellow solution of compound **X**, which has the composition by mass, Na, 26.4%; S, 73.6%.

(i) What is meant by the term *empirical formula*?

.....

..... [1]

(ii) Use this information to prove that **X** has an empirical formula of NaS_2.
Show your working.

[2]

(iii) The sulfur-containing ion in compound **X** consists of a chain of sulfur atoms with an overall 2− charge.

Deduce how many sulfur atoms are in the chain of the ion.

..... atoms [1]

(iv) When solid **X** is added to an excess of acid, an oily liquid results that is immiscible with water. Assume that there is only one sulfur-containing product.

Suggest the structure of this product.

[1]

[Total: 12]

4. The following hard materials have all found use in body armour.

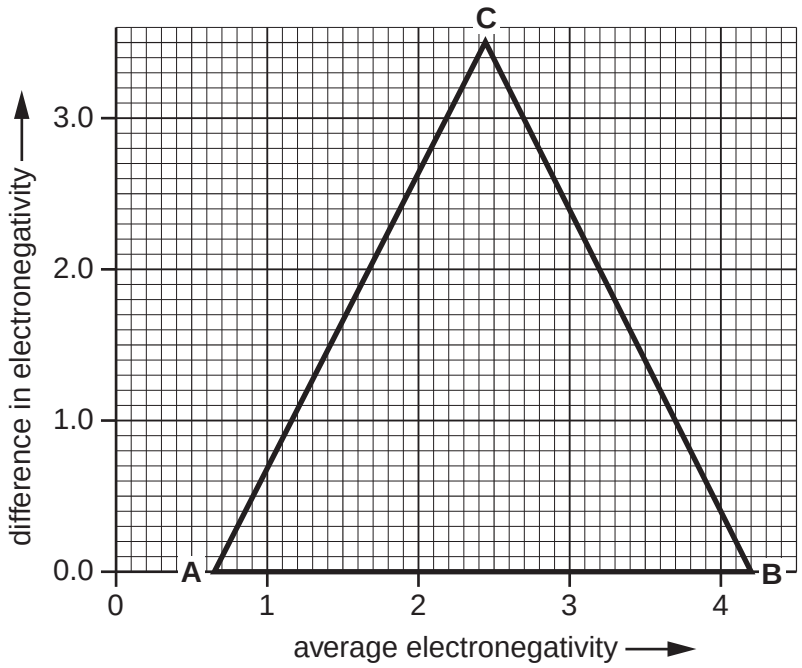
AlN Al_2O_3 B_4C SiC Si_3N_4 TiB_2 WC

Table 3.1 gives the electronegativity values for the elements in these materials.

Table 3.1

element	electronegativity	element	electronegativity
titanium	1.4	boron	2.1
tungsten	1.5	carbon	2.5
aluminium	1.6	nitrogen	3.1
silicon	1.9	oxygen	3.6

(a) Plot on the van Arkel triangle the points corresponding to silicon carbide, SiC, and silicon nitride, Si_3N_4. Label your points, making it clear which is which. [2]



(b) Point **A** on the van Arkel triangle corresponds to metallic bonding. State the types of bonding that correspond to points **B** and **C**.

B ..... **C** ..... [1]

(c) Compare the bonding in silicon carbide, SiC, with silicon nitride, Si_3N_4, by circling the correct option.

SiC is **less metallic** **equally metallic** **more metallic** [1]

(d) Circle the correct response about the bonding in silicon carbide, SiC. The bonding in silicon carbide is best described as [1]

intermediate between metallic and covalent

metallic

intermediate between metallic and ionic

(e) Which of the hard materials, AlN, Al_2O_3 and TiB_2, is most intermediate between all three extremes of bonding?

.....[1]

(f) Scientists have recently characterised metallic behaviour in VO_2 above 68 °C (*Nature Nanotechnology*, 2009). The same behaviour was not found in V_2O_5. By considering this case and the electrical properties of diamond and graphite suggest three **general** deficiencies in the predictive power of the van Arkel triangle.

1 .....

2 .....

3 .....[3]

[Total: 9]

5. The Intel® super-fast 45 nm Core 2 processors are based on Penryn technology. This involves the use, for the first time in computer chips, of an oxide of hafnium.

(a) This oxide of hafnium has the formula HfO_2. Calculate the percentage of hafnium by mass in this oxide.

.....% [1]

(b) Table 2.1 provides the electronegativity data for O and Hf.

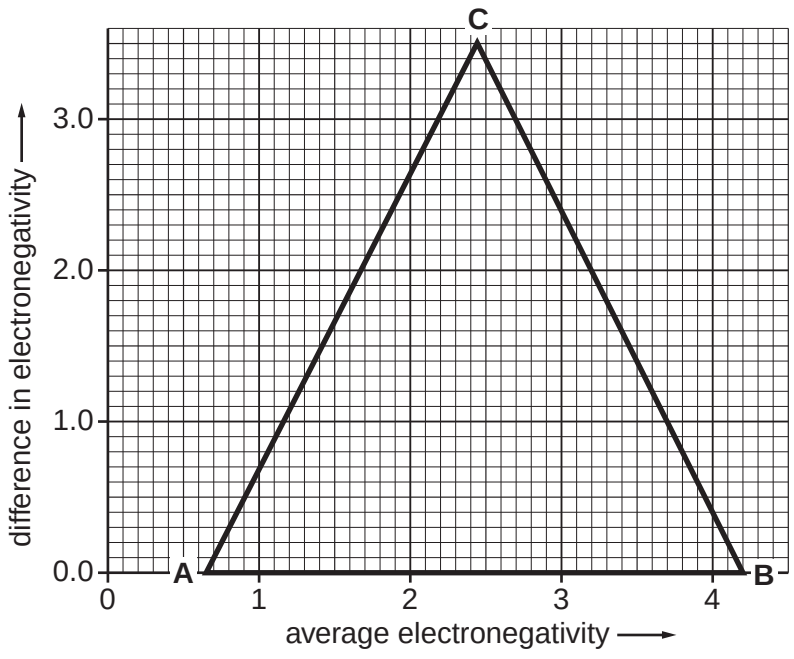
Table 2.1

element	electronegativity
O	3.61
Hf	1.16

Computer chips contain electrical conductors, semiconductors and insulators. On the van Arkel triangle mark the point corresponding to the oxide of hafnium and use this point to deduce its electrical properties. Ring the correct option.

The oxide of hafnium is

conductor **semiconductor** **insulator**



[2]

(c) Use your van Arkel plot to decide whether the oxide of hafnium is best described as ionic, covalent or metallic. Ring the correct option below.

The oxide of hafnium is best described as

ionic **covalent** **metallic** [1]

(d) Elemental hafnium has neutron-absorbing properties that are useful in nuclear reactors. It can be extracted from the oxide, HfO_2, by the following reactions.

reaction 1 reaction with hydrochloric acid
reaction 2 reduction of a product of **reaction 1** with magnesium

Write balanced equations for these reactions.

equation for **reaction 1**

.....

equation for **reaction 2**

.....[2]

[Total: 6]