Atoms

Question Paper

Level	Pre U
Subject	Chemistry
Exam Board	Cambridge International Examinations
Topic	Atoms-Physical Chemistry
Booklet	Question Paper

Time Allowed: **47 minutes**

Score: **/39**

Percentage: **/100**

Grade Boundaries:

1. (a) (i) What is meant by the term *bond energy*?

.....

.....

..... [3]

(ii) Use the bond energy data in Table 2.1 to find the enthalpy change of reaction for the reaction between ethane and chlorine shown below.

$$C_2H_6(g) + 2Cl_2(g) \longrightarrow C_2H_4Cl_2(g) + 2HCl(g)$$

Table 2.1

bond	average bond energy / kJ mol^{-1}
C−C	347
C−H	413
Cl−Cl	243
C−Cl	346
H−Cl	432

[3]

(b) At low temperatures and pressures the alkali metals can exist as gaseous diatomic molecules. Recent research has investigated the mixing of gaseous diatomic molecules of different alkali metals (reported in *Science* 2010).

Spectroscopic techniques can be used to measure the bond energies of diatomic molecules. When measured in this way the values of bond energies are given in wavenumbers, which has the unit cm^{-1}.

Some values are shown in Table 2.2.

Table 2.2

diatomic molecule	bond energy / cm^{-1}
K_2	4405
Rb_2	3966
KRb	4180

(i) Calculate the enthalpy change, in cm^{-1}, for the reaction between K_2 and Rb_2.

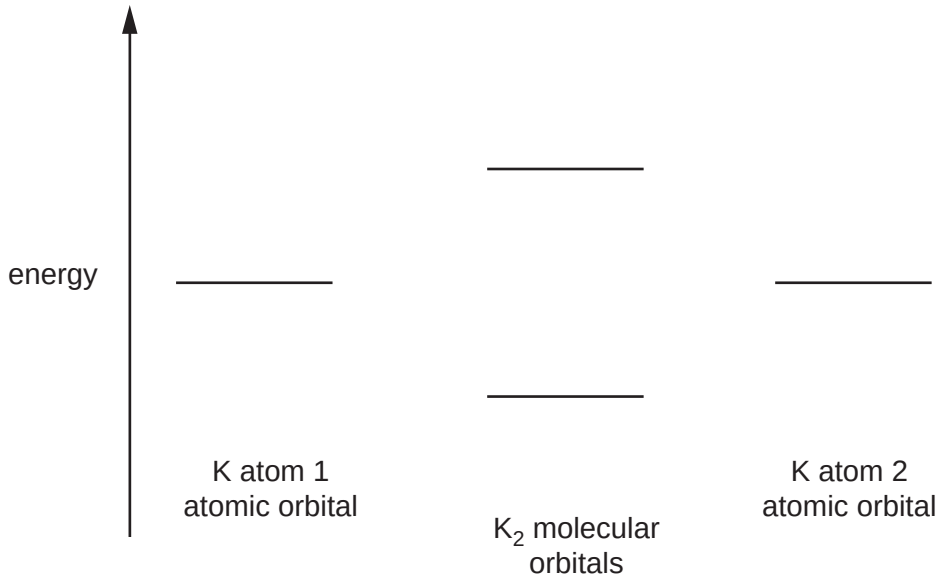
$$K_2(g) + Rb_2(g) \rightarrow 2KRb(g)$$

..... cm^{-1} [1]

(ii) Complete the electron configuration of a potassium atom.

$1s^2$ ..... [1]

(iii) If only the outer shell electrons are considered, the molecular orbital diagram for an alkali metal diatomic molecule is much like that for hydrogen, H_2. Label all the orbitals in the molecular orbital diagram for K_2 and include the electrons.



[3]

(iv) Explain why potassium has a greater first ionisation energy than rubidium.

.....

.....

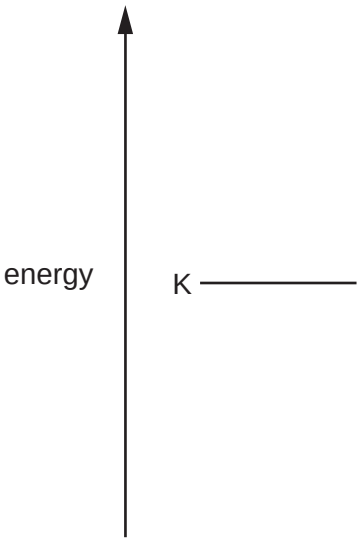
.....

.....

.....

..... [3]

(v) Complete the molecular orbital diagram for KRb, showing relevant atomic and molecular orbitals. Only include outer shell orbitals. Label all the orbitals in your diagram.



[2]

(vi) Wavenumbers, $\bar{\nu}$, are converted into energy, E, using the equation

$$E = h c \bar{\nu}$$

where h is Planck's constant and c is the speed of light.

Using your answer to **(b)(i)**, work out the enthalpy change in $kJ\,mol^{-1}$ for the reaction between K_2 and Rb_2.

..... $kJ\,mol^{-1}$ [2]

[Total: 18]

2. The scientific community was shocked at the recent claim of the discovery of an isotope of a new element with a mass number of 292 (published in *arXiv*, 2008): this is over 50 mass units higher than uranium, the heaviest known naturally-occurring element. There is a possibility that there is an 'island of stability' beyond the known Periodic Table at some very high atomic numbers.

(a) The authors of this claim suggested that the atomic number of the element is 122. How many neutrons are there in this isotope?

.....[1]

(b) If this element really exists then it will require a new block of the periodic table, corresponding to the occupancy of another type of subshell, beyond the *s*, *p*, *d* and *f*. This would be a *g* subshell, which is predicted to be found in the 5th shell of an atom, i.e. the 5g subshell.

Based upon the sequence of subshells in the Periodic Table, *s*, *p*, *d*, *f*, predict how many orbitals there are in a *g* subshell.

.....[1]

(c) Predict how many elements there would be in the first row of the *g*-block.

.....[1]

Below is a scheme of the 17 lowest energy subshells, which can be used to show the order in which the subshells are filled by electrons (the Aufbau principle).

1s 2s 7s

2p

3d

4f

(d) List the order of filling subshells from 4p to 5d.

.....[1]

(e) The subshells in the scheme above are those that are occupied by the elements up to uranium. Add to the above diagram the next four subshells that would be expected to be filled. [1]

(f) Following the Aufbau principle, how many electrons in the 5g subshell would element 122 be expected to have?

.....[1]

[Total: 6]

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

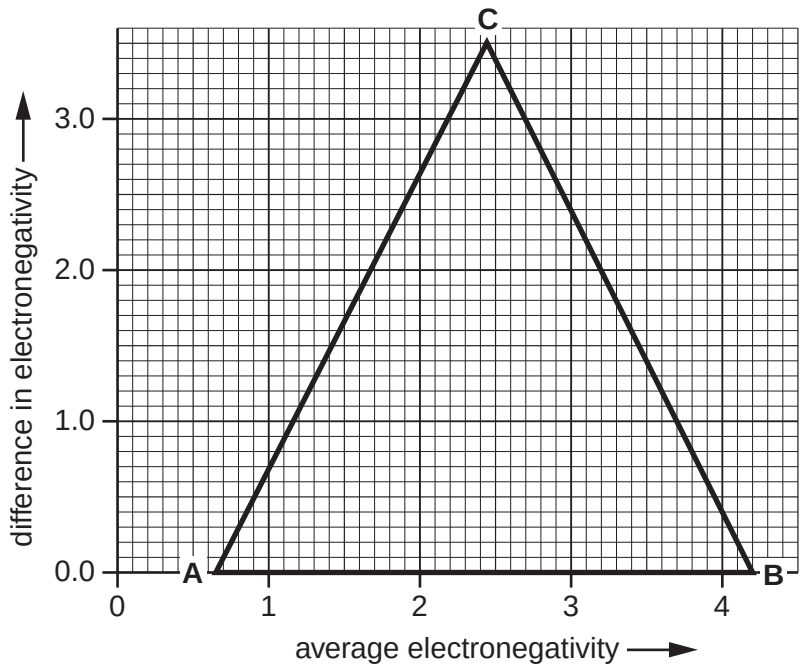
AlN Al_2O_3 B_4C SiC Si_3N_4 TiB_2 WC

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]

4. 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.

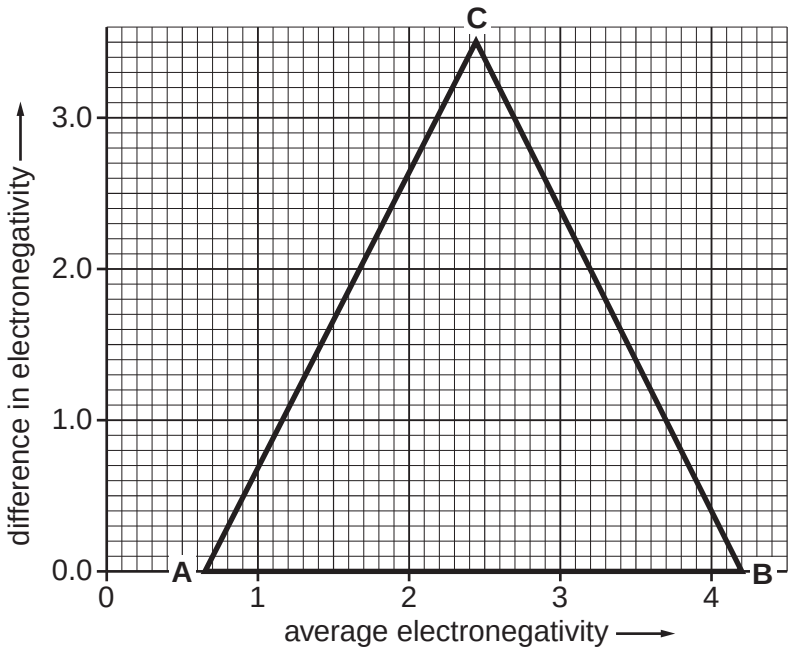
Table 2.1

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**



[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 **valent** **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]