AH Exercise 1.2a

Electronic Configuration

2003 AH MC6 (80%) and 2013 AH MC5 (70%)

6. When electrons occupy degenerate orbitals, they do so in such a way as to maximise the number of parallel spins. This statement is known as

A the Pauli exclusion principle

B Heisenberg's uncertainty principle

C the aufbau principle

D Hund's rule.

2004 AH MC1 (88%)

1. According to the aufbau principle, electrons fill orbitals in the order

A 1s 2s 2p 3s 3p 4s 4p 3d

B 1s 2s 2p 3s 3d 3p 4s 4p

C 1s 2s 2p 3s 3p 3d 4s 4p

D 1s 2s 2p 3s 3p 4s 3d 4p.

2007 AH MC9 (57%)

9. The statement that "an orbital can accommodate, at most, two electrons, and if so, they must be of opposite spin" is based on

A Hund's rule

B the aufbau principle

C the Pauli exclusion principle

D Heisenberg's uncertainty principle.

2013 revAH MC5 (81%)

5. When electrons occupy degenerate orbitals, they do so in such a way as to maximise the number of parallel spins. This statement is known as

A Hund's rule

B the aufbau principle

C the Pauli exclusion principle

D Valence Shell Electron Pair Repulsion (VSEPR) theory.

2006 AH MC7 (85%)

7. Hund's rule states that

A it is impossible to define both the position and momentum of an electron simultaneously

B electrons occupy orbitals in order of increasing energy

C electrons occupy degenerate orbitals singly with parallel spins before spin pairing occurs

D the energy of an electron in an atom is quantised.

2014 revAH MC5 (87%)

5. The Pauli Exclusion Principle states that

A electrons fill degenerate orbitals singly

B electrons fill orbitals in order of increasing energy

C when degenerate orbitals are half filled all their electrons have parallel spins

D no two electrons in the one atom can have the same set of four quantum numbers.

2016 AH MC2 (92%)

2. Which of the following states that electrons fill orbitals in order of increasing energy?

A Hund's rule

B The aufbau principle

C The Pauli exclusion principle

D The valence shell electron pair repulsion theory

2014 revAH MC1 (70%)

1. The quantum number which specifies the shape of an orbital is the

A principal quantum number

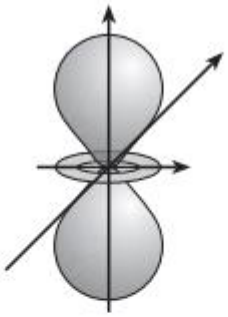
B angular momentum quantum number

C magnetic quantum number

D spin quantum number.

2007 AH MC10 (72%)

10.



The above is a diagrammatic representation of the shape of

A any p-orbital

B a specific p-orbital

C any d-orbital

D a specific d-orbital.

2007 AH MC4 (44%)

4. **All** noble gases are characterised in terms of electrons by the completion of the outermost orbital. This orbital is

A an s-orbital

B a p-orbital

C a d-orbital

D an s or p-orbital.

2014 revAH MC2 (89%)

2. Element number 104 in the Periodic Table is

A an s-block element

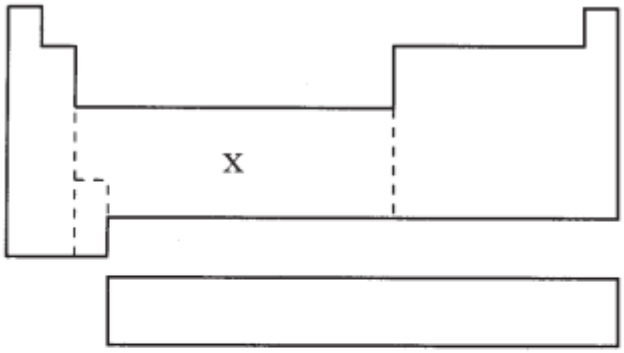
B a p-block element

C a d-block element

D an f-block element.

2005 AH MC1 (92%) and 2016 AH MC3 (94%)

1.



In the Periodic Table outlined above, one area is marked "X". Moving across area "X", from one element to the next, the extra electron usually occupies an orbital of type

A s

B p

C d

D f.

2008 AH MC1 (37%)

1. An atom has the electronic configuration

$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^1$

What is the charge of the most likely ion formed from this atom?

A −1

B +1

C +2

D +3

2010 AH MC2 (61%)

2. An atom has the electronic configuration

$1s^2\ 2s^2\ 2p^6 3s^2\ 3p^1$

What is the charge on the most probable ion formed by this element?

A +1

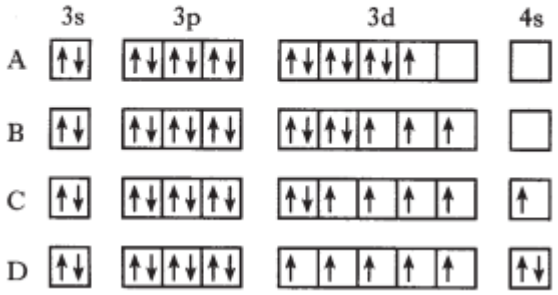
B +2

C +3

D +4

2005 AH MC3 (80%)

3. Which of the diagrams below correctly represents the distribution of electrons in the outer orbitals of an atom in its ground state?



2001 AH MC11 (75%)

11. Which of the following correctly describes an atom of nickel in its ground state?

A It has one empty d-orbital.

B It contains 12 electrons in p-orbitals.

C All orbitals in the 3rd shell are full.

D It contains no unpaired electrons.

2008 AH MC2 (69%)

2. The electronic configurations, **X** and **Y**, for two uncharged atoms of sodium are as follows.

X $1s^2\ 2s^2\ 2p^6\ 3s^1$
Y $1s^2\ 2s^2\ 2p^6\ 4s^1$

Which of the following statements is true?

A **X** is an excited state.

B Both **X** and **Y** have vacant 2d orbitals.

C Energy is absorbed in changing **Y** to **X**.

D Less energy is required to ionise **Y** compared to **X**.

2013 AH MC6 (62%) and 2013 revAH MC6 (56%)

6. Which of the following represents the configuration of the highest energy electrons in an atom of a Group III element in the ground state?

A $3s^2 3p^1$

B $3s^2 3p^3$

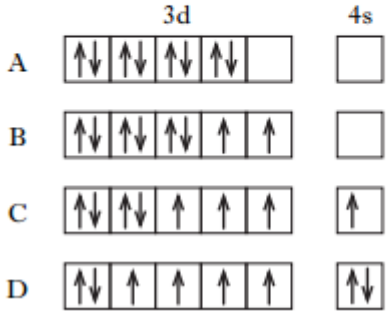
C $4s^2 3d^1$

D $4s^2 4p^3$

2010 AH MC1 (86%)

1. An atom of iron contains 26 electrons.

Which of the following diagrams below correctly represents the distribution of electrons in the 3d and 4s orbitals in an atom of iron in its ground state?



2014 AH MC3 (80%) and 2014 revAH MC10 (82%)

3. The electronic configuration of a vanadium atom in its ground state is

A $1s^2 2s^2 2p^6 3s^2 3p^6 3d^5$

B $1s^2 2s^2 2p^6 3s^2 3p^6 4s^2 4p^3$

C $1s^2 2s^2 2p^6 3s^2 3p^6 3d^3 4s^2$

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

2014 revAH MC3 (50%)

3. Which of the following statements is **incorrect** about electronic configurations of all first row transition metal atoms in their ground states?

A The five 3d orbitals are degenerate.

B They all have at least one electron in the 4s orbital.

C Electrons begin to fill the 3d orbitals only after the 4s orbital is full.

D When transition metal atoms form ions, the 4s electrons are lost first.

2002 AH grid32

32. The boxes in the grid below show electronic configurations of different species.

A $1s^2 2s^2 2p^6$	B $1s^2 2s^2 2p^6 3s^1$	C $1s^2 2s^2 2p^6 3p^1$
D $1s^2 2s^2 2p^6 3s^2\ 3p^6 3d^4 4s^2$	E $1s^2 2s^2 2p^6 3s^2\ 3p^6 3d^5 4s^1$	F $1s^2 2s^2 2p^6 3s^2\ 3p^6 3d^6$

(*a*) Which is the electronic configuration of a chromium atom in the ground state?

(*b*) Which is the electronic configuration of a sodium atom in an excited state?

(*c*) Which electronic configuration(s) will have a total of 4 unpaired electrons?

2006 AH L3

3. The table shows two quantum numbers for the 10 electrons in a neon atom.

Electron	First Quantum Number (n)	Second Quantum Number (ℓ)
1	1	0
2	1	0
3	2	0
4	2	0
5	2	1
6	2	1
7	2	1
8	2	1
9	2	1
10	2	1

(*a*) Write the electronic configuration for a neon atom in terms of s and p orbitals. **1**

(*b*) Electrons 5 to 10 can be described as degenerate.
What is meant by the term "degenerate"? **1**

(*c*) The second quantum number, ℓ, is related to the shape of the orbitals.
Draw the shape of an orbital when $\ell = 1$. **1**

(*d*) What are the first and second quantum numbers for the outer electron in a sodium atom? **1**

2. In the periodic table, period 2 is comprised of the elements lithium to neon.

The following table shows two of the quantum numbers for all ten electrons in a neon atom.

Electron	*Principal quantum number, n*	*Angular momentum quantum number, l*
1	1	0
2	1	0
3	2	0
4	2	0
5	2	1
6	2	1
7	2	1
8	2	1
9	2	1
10	2	1

(a) Write the electronic configuration for neon in terms of s and p orbitals. **1**

(b) The angular momentum quantum number, *l*, is related to the shape of an orbital.

Draw the shape of an orbital when *l* has a value of 1. **1**

(c) The magnetic quantum number, *m*, is related to the orientation of an orbital in space.

State the values of *m* for the orbital which contains the tenth electron. **1**

2008 AH L3a+b

3. Some metal salts emit light when heated in a Bunsen flame.

Lithium nitrate changes the flame colour to crimson.

Magnesium nitrate has no effect on the flame colour.

(*a*) Explain, in terms of electrons, why some metal salts emit light when heated in a Bunsen flame. **1**

(*b*) Suggest why magnesium nitrate has no effect on the flame colour. **1**

2009 AH L1a

1. A detector in a Geiger counter contains argon which ionises when nuclear radiation passes through it.

(*a*) Write the electronic configuration for argon in terms of s and p orbitals. **1**

2012 AH L1a(ii)

1. Semiconductors are used in a wide variety of applications.

(*a*) In Blu-ray DVD players, light of wavelength 405 nm is produced from a gallium(III) nitride laser.

(ii) Write the electronic configuration of gallium(III) in terms of s, p and d orbitals. **1**

2013 revAH L1a+b

1. The electronic configuration of a carbon atom is $1s^2 2s^2 2p^2$.

(*a*) The electrons in the 2p orbitals are said to be "degenerate".

What is meant by the term "degenerate"? **1**

(*b*) Draw the electronic configuration of a carbon atom in orbital box notation. **1**

2014 revAH L1b+c

1. Atomic spectroscopy is a useful analytical tool for identifying and quantifying the elements present in a sample. It also provides information about atomic structure.

(*b*) A helium atom has two electrons in its ground state. One of the electrons can be described by the four quantum numbers 1, 0, 0, +½.

What four quantum numbers describe the other electron? **1**

(*c*) (i) Using orbital box notation, write the electronic configuration for a phosphorus atom in its ground state. **1**

(ii) Explain how your answer is consistent with Hund's rule. **1**

(iii) When a phosphorus atom becomes excited an electron can move to the 4s orbital.

What four quantum numbers describe the excited electron? **1**

2014 AH L4e

4. A chromium compound is known to exist in the following three isomeric forms. The co-ordination number of chromium is the same in each isomer.

A $[Cr(H_2O)_6]^{3+}(Cl^-)_3$

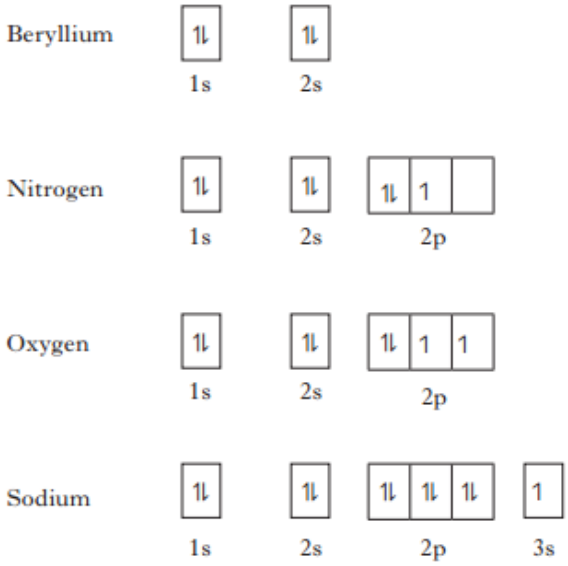
B $[Cr(H_2O)_5Cl]^{2+}(Cl^-)_2.H_2O$

C $[Cr(H_2O)_4Cl_2]^{+}(Cl^-).2H_2O$

(e) State the electronic configuration of **chromium(I)** in terms of s, p and d orbitals. **1**

2015 AH L1a(i) + (ii) + (iii) and 2015 revAH L1a(i) + a(ii)

1. (*a*) A student wrote the following ground state electronic configurations for atoms of beryllium, nitrogen, oxygen and sodium, where ↿ denotes an electron.



(i) The three atomic orbitals in the 2p subshell are said to be degenerate.

What is meant by the term degenerate? **1**

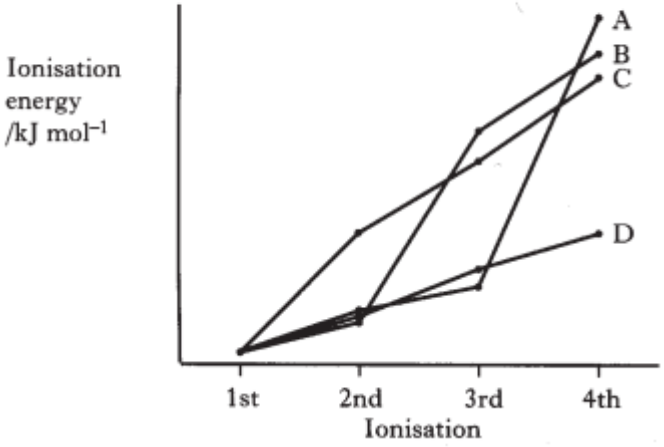
(ii) Explain why the electronic configuration for nitrogen shown above is incorrect. **1**

AH Exercise 1.2b

Ionisation Energy

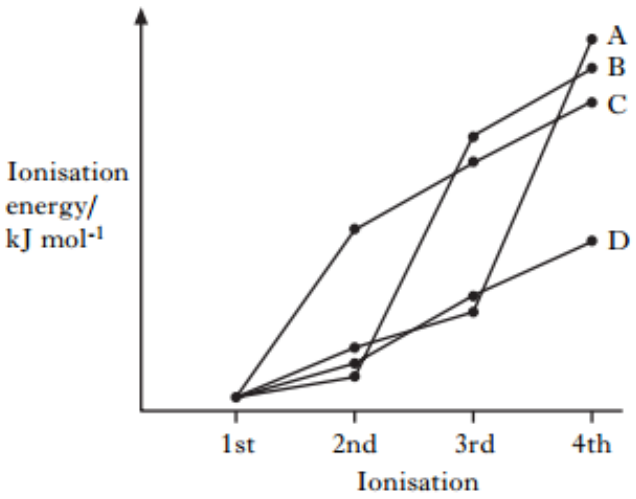
2005 AH MC2 and 2011 AH MC1 (86%)

2. Which of the following graphs represents the trend in successive ionisation energies of a Group 3 element?



2010 AH MC4 (77%)

4. Which line in the graph represents the trend in successive ionisation energies of a Group 2 element?



2013 AH MC1 (90%) and 2013 revAH MC1 (88%)

1. Which equation can be used to represent the second ionisation energy of the diatomic element, X?

A $X_2(g) \rightarrow X_2^{2+}(g) + 2e^-$

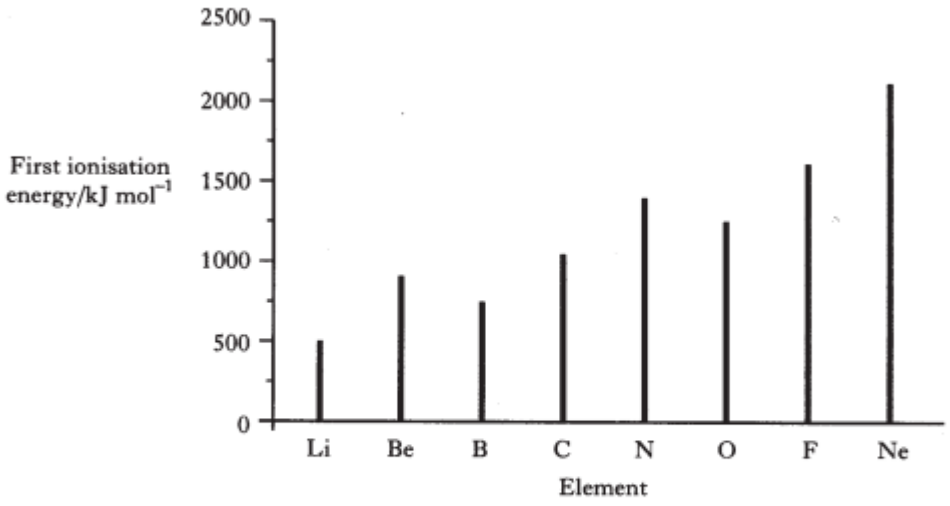
B $\frac{1}{2}X_2(g) \rightarrow X^{2+}(g) + 2e^-$

C $X^+(g) \rightarrow X^{2+}(g) + e^-$

D $X(g) \rightarrow X^{2+}(g) + 2e^-$

2004 AH L1

1. The graph below shows the first ionisation energies for the elements of the second period in the Periodic Table.



(*a*) (i) Why does the first ionisation energy tend to increase across the period? **1**

(ii) Give a reason why the first ionisation energy of nitrogen is higher than that of oxygen. **1**

(*b*) Explain why the **second** ionisation energy of lithium is the highest in this period. **1**

2007 AH L7b

7. The electronic configuration for cobalt, Co, in its ground state, is

$$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^7\ 4s^2.$$

(*b*) (i) Write an equation which represents the second ionisation energy for copper. **1**

(ii) Explain why copper has a higher second ionisation energy than cobalt. **1**

AH Exercise 1.2c

Shapes of Polyatomic Molecules

2002 AH MC21 (43%)

21. Which diagram best represents the arrangement of atoms in the IF_4^- ion?

Note: ⊙ represents a lone pair of electrons.

A

B

C

D

<u>2005</u> AH MC9 (57%) and 2011 AH MC4 (66%)

9. What is the change in the three-dimensional arrangement of the bonds round the P atom in the following reaction?

$$PF_5 \rightarrow PF_3 + F_2$$

A Trigonal bipyramidal to trigonal planar

B Tetrahedral to pyramidal

C Octahedral to trigonal planar

D Trigonal bipyramidal to pyramidal

2006 AH MC2 (59%)

2. What is the change in the three-dimensional arrangement of the bonds round the B atom in the following reaction?

$$BF_4^- \rightarrow BF_3 + F^-$$

A Square planar to trigonal planar

B Tetrahedral to trigonal planar

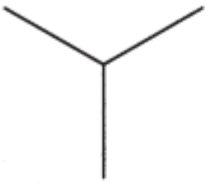
C Tetrahedral to pyramidal

D Square planar to pyramidal

2004 AH MC6 (57%) + 2004 AH MC7 (56%)

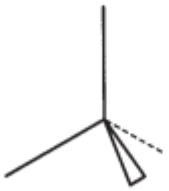
Questions 6 and **7** refer to the following diagrams which indicate different arrangements of **electron pairs**.

A



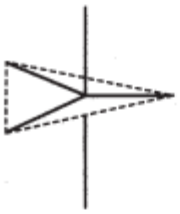
trigonal planar

B



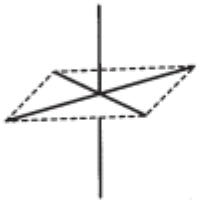
tetrahedral

C



trigonal bipyramidal

D



octahedral

Which arrangement of electron pairs will be found in the following molecules?

6. NF_3

7. ClF_3

2007 AH MC6 (71%)

6. When an ammonia molecule accepts a proton to form an ammonium ion, there is a change of shape from

A pyramidal to tetrahedral

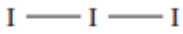
B pyramidal to trigonal planar

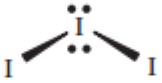
C trigonal planar to pyramidal

D trigonal planar to tetrahedral.

2009 AH MC4 (49%)

4. Which of the following diagrams best represents the arrangement of electron pairs around the central iodine atom in the I_3^- ion?

A 

B 

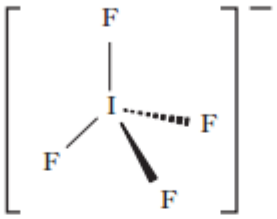
C 

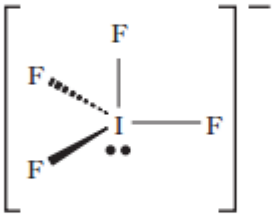
D 

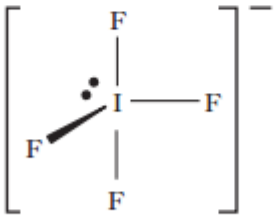
2010 AH MC6 (53%)

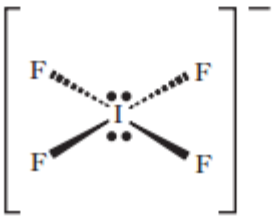
6. Which of the following diagrams best represents the arrangement of atoms in the IF_4^- ion?

Note: a lone pair of electrons is represented by ••

A 

B 

C 

D 

2016 AH MC4 (64%)

4. Which of the following molecules contains three atoms in a straight line?

A BF_3

B CH_4

C H_2O

D SF_6

2012 AH MC6 (57%)

6. Which of the following molecules has three atoms in a straight line?

A H_2O

B SF_6

C CH_4

D C_2H_3Br

2013 AH MC11 (63%) and 2013 revAH MC9 (69%)

11. The following diagram represents a square-planar structure.

Where ▬ and ▬ represent bonding electron pairs

and ⊙ represents a non-bonding electron pair (lone pair).

Which of the following species could have the structure shown above?

A SF_4

B NH_4^+

C XeF_4

D AlH_4^-

2014 AH MC7 (70%) and 2014 revAH MC9 (75%)

7. Which of the following does **not** have a pyramidal structure?

A BF_3

B NH_3

C OH_3^+

D PH_3

2015 AH MC6 (73%)

6. Which of the following species has the same shape as an ammonia molecule?

A BH_3

B CH_3^+

C CH_3^-

D CO_3^{2-}

2014 AH MC6 (61%) and 2014 revAH MC8 (70%)

6. Which of the following has bond angles equal to 90°?

A SF_6

B NH_4^+

C $SiCl_4$

D BeF_4^{2-}

2015 revAH MC5 (84%)

5. Which line in the table represents the shape and the number of bonding and non-bonding pairs of electrons in the H_3O^+ ion?

	Shape	**Bonding pairs**	**Non-bonding pairs**
A	tetrahedral	2	2
B	pyramidal	3	1
C	pyramidal	3	0
D	trigonal planar	3	0

<u>2004</u> AH MC2 (65%) and 2008 AH MC3 (74%) and <u>2015</u> AH MC5 (77%) and 2015 revAH MC4 (75%)

2. A Lewis base may be regarded as a substance which is capable of donating an unshared pair of electrons to form a covalent bond.

Which of the following could act as a Lewis base?

A BCl_3

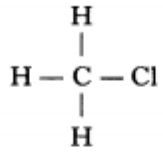
B NH_4^+

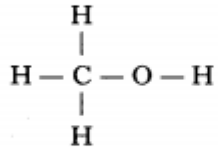
C PH_3

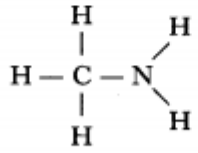
D Co^{3+}

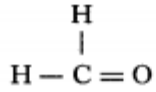
2006 AH MC5 (59%) and 2011 AH MC3 (77%) and 2013 AH MC10 (79%) and 2013 revAH MC8 (72%)

5. Which of the following molecules has the greatest number of non-bonding electron pairs (lone pairs)?

A 

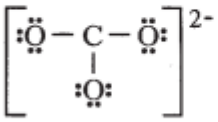
B 

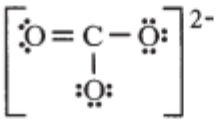
C 

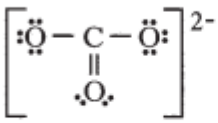
D 

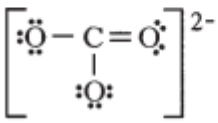
2005 AH MC7 (87%)

7. Which of the following representations is the least likely resonance structure for a carbonate ion?

A 

B 

C 

D 

2009 AH MC3 (74%)

3. In which of the following species is a dative covalent bond present?

A H_3O^+

B H_2O

C OH^-

D O_2

2013 AH MC9 (78%)

9. Which of the following substances contains a dative covalent bond?

A NH_3

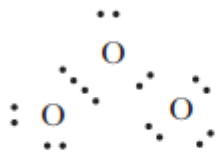
B NCl_3

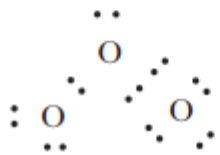
C NH_4Cl

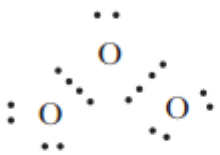
D CH_3NH_2

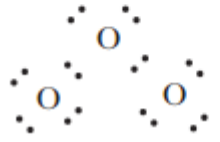
2013 AH MC8 (61%)

8. Which of the following represents a valid Lewis electron dot diagram for ozone, O_3?

A 

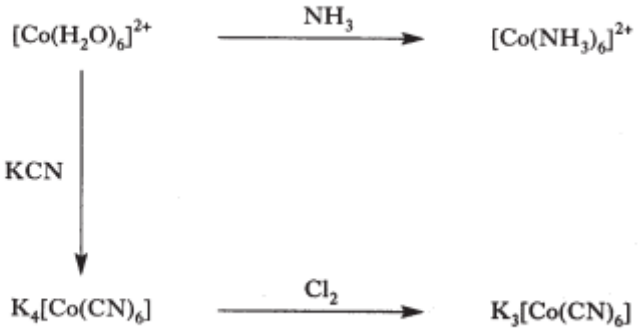
B 

C 

D 

2004 AH L5a

5. Consider the following reactions.



(*a*) Write the electronic configuration of the cobalt(II) ion in terms of s, p and d orbitals. **1**

2006 AH L4b(ii)

4. In the stratosphere, oxygen molecules absorb ultraviolet radiation and break up to form oxygen atoms.

$$O=O \longrightarrow O + O$$

(*b*) Some of the oxygen atoms react with oxygen molecules to produce ozone, O_3.

Reaction 1 $O + O_2 \longrightarrow O_3$ $\quad \Delta H° = -106\ kJ\ mol^{-1}$

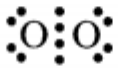
Other oxygen atoms react to produce oxygen molecules.

Reaction 2 $O + O \longrightarrow O_2$ $\quad \Delta H° = -497\ kJ\ mol^{-1}$

Oxygen atoms can also react with ozone to produce oxygen molecules.

Reaction 3 $O + O_3 \longrightarrow O_2 + O_2$

(ii) A Lewis dot diagram for an oxygen molecule is



Draw a similar diagram for an ozone molecule. **1**

2008 AH L1

1. (*a*) What is the arrangement of the **electron pairs** around the iodine atom in an IF_5 molecule? **1**

(*b*) By considering the electron pairs, explain why the bond angle in BF_3 is greater than the bond angle in NF_3. **1**

2001 AH grid 32b+c

32. The boxes in the grid below contain formulae of some compounds.

A CO_2	B PCl_5	C $AlCl_3$
D CuO	E PCl_3	F $LiAlH_4$

(*b*) Identify the compound which has molecules that are trigonal bipyramidal in shape.

(*c*) Identify the compound which has linear molecules.

2002 AH L2

2. The shapes of molecules depend on the number of bonding and non-bonding electron pairs present.

(*a*) Draw a diagram to show the molecular shape of

(i) methane

(ii) hydrogen sulphide. **1**

(*b*) Explain why the bond angle in hydrogen sulphide is less than that in methane. **2**

2003 AH L1

1. In the reaction

$$NH_3(aq) + H^+(aq) \rightarrow NH_4^+(aq)$$

a **dative** covalent bond is formed.

(*a*) What is meant by a **dative** covalent bond? **1**

(*b*) Draw the Lewis electron dot diagram for the ammonium ion. **1**

(*c*) Draw a diagram which shows the three dimensional shape of an ammonium ion. **1**

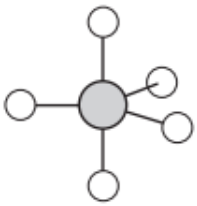
2004 AH L7a

7. Ozone, O_3, is one of the earth's key defences against damaging ultra-violet radiation.

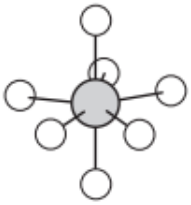
(*a*) Ozone can be described in terms of resonance structures.
Draw the **two** resonance structures for ozone. **1**

2009 AH L12b+d

12. Many interhalogen compounds exist. Two of these are iodine pentafluoride and iodine heptafluoride.



IF_5



IF_7

(*b*) Name the shape adopted by the iodine pentafluoride molecule. **1**

(*d*) Another interhalogen compound, ClF_5, exists but ClF_7 does not.
Suggest a reason why ClF_7 does not exist. **1**

2010 AH L1b

1. The first argon compound was prepared by shining light of wavelength 160 nm onto a mixture of argon and hydrogen fluoride at a temperature of 7·5 K. The hydrogen fluoride reacted with the argon to form HArF.

(*b*) Supposing HArF is covalent,

(i) predict the total number of electron pairs, bonding and non-bonding, which surround the Ar atom in the HArF molecule. **1**

(ii) what shape do the electron pairs around the Ar atom in an HArF molecule adopt? **1**

2011 AH L3b

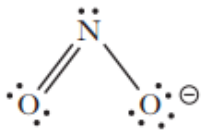
3. When a mixture of nitrogen monoxide and nitrogen dioxide is cooled to –20 °C they react to form the clear blue liquid, dinitrogen trioxide.

$$NO + NO_2 \rightarrow N_2O_3$$

(*b*) Dinitrogen trioxide neutralises aqueous sodium hydroxide forming sodium nitrite and water.

The nitrite ion, NO_2^-, can be represented by two resonance structures.

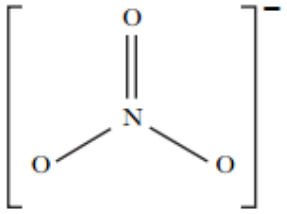
One of these is



Draw the other resonance structure. **1**

2010 AH L5

5. The nitrate ion has three equivalent resonance structures. One of these structures is shown below.

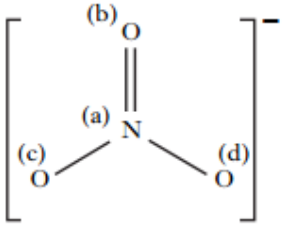


(*a*) Draw a similar diagram to show one of the other two resonance structures. **1**

(*b*) The formal charge on an atom in a resonance structure can be found using the expression

$$\text{Formal charge} = \left(\begin{array}{c}\text{Group in}\\ \text{Periodic Table}\end{array}\right) - \left(\begin{array}{c}\text{Number of lone pair}\\ \text{electrons}\end{array}\right) - \tfrac{1}{2}\left(\begin{array}{c}\text{Number of bonding}\\ \text{electrons}\end{array}\right).$$

Use this expression to find the formal charge on atoms (b), (c) and (d) shown in the table below.

Resonance structure	Atom	Formal charge
	(a)	+1
	(b)	?
	(c)	?
	(d)	?

2

2012 AH L14b(i)

14.

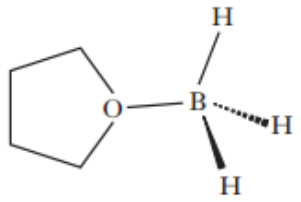
(*b*) Benzene also reacts with sulphur trioxide dissolved in concentrated sulphuric acid to produce benzenesulphonic acid, $C_6H_5SO_3H$.

(ii) Draw a Lewis electron dot diagram for sulphur trioxide. **1**

2012 AH L4a+b

4. BH_3 in the gas phase is very reactive. It readily combines with the compound tetrahydrofuran, C_4H_8O, to make a more stable compound.

$$BH_3 + C_4H_8O \rightarrow C_4H_8OBH_3$$



(*a*) What is the shape of a BH_3 molecule? **1**

(*b*) In the more stable compound a dative covalent bond exists between the boron and oxygen.

How does this dative covalent bond form? **1**

2014 AH L1d

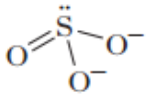
1. Consider the following compounds

$NaCl$ Na_2O MgO Al_2O_3 $SiCl_4$ PCl_3

(*d*) What is the shape of a PCl_3 molecule? **1**

2014 AH L2a+b

2. A resonance structure for the sulphite ion is



(*a*) Draw another resonance structure for the sulphite ion. **1**

(*b*) Draw a Lewis electron dot diagram for the sulphite ion. **1**