Section A

1)
A molecule is

☐ **A** a group of atoms bonded by ionic bonds.

☐ **B** a group of atoms bonded by covalent bonds.

☐ **C** a group of ions bonded by covalent bonds.

☐ **D** a group of atoms bonded by metallic bonds.

(Total for Question 1 = 1 mark)

2)
The relative atomic mass is defined as

☐ **A** the mass of an atom of an element relative to 1/12 the mass of a carbon-12 atom.

☐ **B** the mass of an atom of an element relative to the mass of a hydrogen atom.

☐ **C** the average mass of an element relative to 1/12 the mass of a carbon atom.

☐ **D** the average mass of an atom of an element relative to 1/12 the mass of a carbon-12 atom.

(Total for Question 2 = 1 mark)

3)
The definition of the mole is

☐ **A** the amount of any substance which occupies a volume of 24 dm^3 at room temperature and pressure.

☐ **B** the amount of any substance containing the same number of identical entities as there are in exactly 12 g of the carbon-12 isotope.

☐ **C** the number of atoms in exactly 12 g of the carbon-12 isotope.

☐ **D** the number of molecules in exactly 2 g of hydrogen at room temperature and pressure.

(Total for Question 3 = 1 mark)

4)
The first eight ionization energies of an element are (in kJ mol^{-1}):

789, 1577, 3232, 4356, 16091, 19785, 23787, 29253.

The element is in

☐ **A** Group 1

☐ **B** Group 2

☐ **C** Group 3

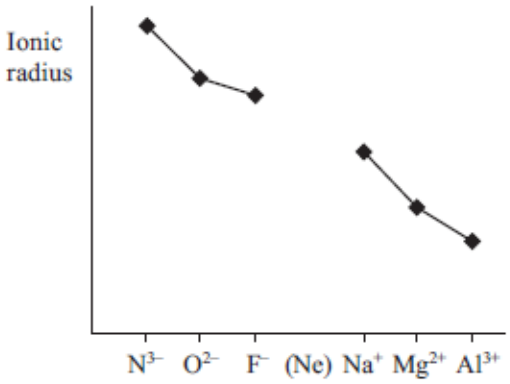
☐ **D** Group 4

1 mark)

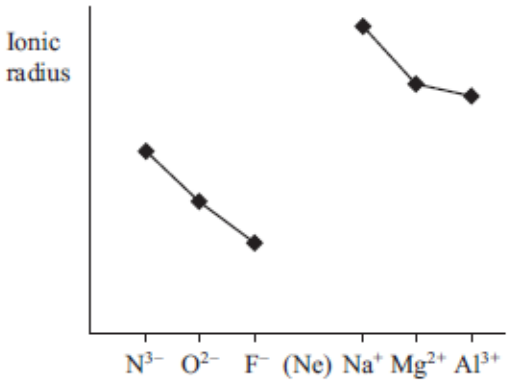
5)

Which of the graphs shows (from left to right) the trend in the ionic radius of the isoelectronic ions N^{3-}, O^{2-}, F^-, Na^+, Mg^{2+}, Al^{3+}?

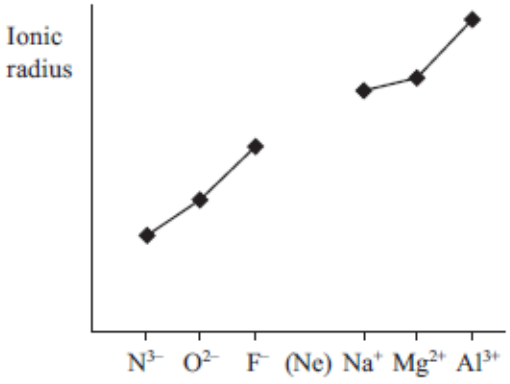
☐ **A**



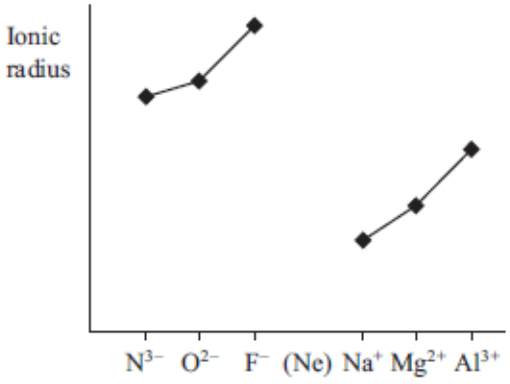
☐ **B**



☐ **C**



☐ **D**



1 mark)

6)

Covalent bonding results from the strong electrostatic attractions between

☐ **A** instantaneous dipoles.

☐ **B** electron clouds.

☐ **C** electrons in the bonding pair. **1 mark)**

☐ **D** bonding pairs of electrons and nuclei.

7)

A solution contains 66 ppm of a solute. The mass of the solute dissolved in 1 kg of this solution is

☐ **A** 66 g

☐ **B** 0.66 g

☐ **C** 0.066 g

☐ **D** 0.000066 g

1 mark)

8)

Complete combustion of 50 cm^3 of a hydrocarbon vapour gave 350 cm^3 of carbon dioxide, both gas volumes being measured at the same temperature and pressure. The formula of the hydrocarbon could be

☐ **A** C_8H_{18}

☐ **B** C_7H_{16}

☐ **C** C_6H_{14}

☐ **D** C_5H_{12}

1 mark)

9)

Which of the following statements is true? The Avogadro constant is the number of

☐ **A** grams of any element which contains 6.02×10^{23} atoms of that element.

☐ **B** atoms contained in one mole of any element.

☐ **C** atoms contained in one mole of any monatomic element.

☐ **D** particles (atoms, molecules or ions) required to make one gram of a substance.

1 mark)

10)

In which of the following cases would a cation be most polarizing?

	Radius	Charge
☐ **A**	small	small
☐ **B**	small	large
☐ **C**	large	small
☐ **D**	large	large

1 mark)

11)

Magnesium chloride, $MgCl_2$, has two lattice energy values quoted in the data booklet. The first is the experimental value, obtained from the Born-Haber cycle, -2526 kJ mol^{-1}; the second is the theoretical value, -2326 kJ mol^{-1}. Why are the two values different?

☐ **A** The cation polarizes the anion leading to some covalent bonding.

☐ **B** The anion polarizes the cation leading to some covalent bonding.

☐ **C** Magnesium chloride is a covalent substance.

☐ **D** The results from the Born-Haber cycle are too inaccurate to be reliable.

1 mark)

Section B

12)

(a) Define the term **first ionization energy**.

(2)

*(b) Explain why the first ionization energy of the elements down Group 1 decreases even though the atomic number increases.

(2)

(c) The eleven successive ionization energies for sodium are given below.

Electron removed	1	2	3	4	5	6	7	8	9	10	11
Ionization energy / kJ mol^{-1}	496	4563	6913	9544	13352	16611	20115	24491	28934	141367	159079

(i) Explain why the successive ionization energies increase.

(1)

*(ii) Explain how these ionization energies give evidence for the electronic structure of sodium. You may use a sketch graph if you wish.

(2)

(d) The first ionization energy of aluminium (element 13) is lower than that of magnesium (element 12).

(i) Give the electronic structures of magnesium and of aluminium in *s*, *p* and *d* notation.

(1)

Magnesium .....

Aluminium .....

*(ii) Explain the difference in the first ionization energies of the two metals.

(1)

13)

(a) Explain how the atoms are held together by the covalent bond in a molecule of hydrogen.

(1)

(b) Draw the dot and cross diagrams for

(i) methane, CH_4

(1)

(ii) ethene, $CH_2{=}CH_2$

(1)

(iii) nitrogen, N_2

(1)

(iv) the ammonium ion, NH_4^+

(1)

(c) Silicon exists in a giant covalent lattice.

(i) The electrical conductivity of pure silicon is very low. Explain why this is so in terms of the bonding.

(2)

(ii) Explain the high melting temperature of silicon in terms of the bonding.

(2)

14)

Fuel from the air?

A new catalyst that can break down carbon dioxide gas could allow us to use carbon from the atmosphere as a fuel source in a similar way to plants.

Plants break the stable bonds in carbon dioxide during photosynthesis. In the natural process, the carbon dioxide molecule is initially bonded to nitrogen atoms, making reactive compounds called carbamates. Carbamates are derivatives of carbamic acid, NH_2CO_2H. These compounds can then be broken down, allowing the carbon to be used in the synthesis of other plant products such as sugars and proteins.

A new catalyst produced by scientists is a graphite-like compound made from flat layers of carbon and nitrogen atoms arranged in hexagons. Carbon dioxide binds to the catalyst and takes part in the following reaction, which occurs at 150 °C and at about three times atmospheric pressure.

$$\underset{\text{benzene}}{C_6H_6} + CO_2 \rightarrow \underset{\text{phenol}}{C_6H_5OH} + CO$$

Carbon monoxide can then be used to make liquid fuels such as methanol.

The energy required for photosynthesis comes from light, and experiments are now going on to develop a light activated catalyst which could break down carbon dioxide in a new process.

(Source: adapted from an article from the *NewScientist.com* by Tom Simonite, March 2007)

(a) Why are the bonds **within** a layer of carbon atoms in graphite stronger than the bonds **between** the layers of carbon atoms?

(2)

(b) The data below gives the relative electrical conductivity of a pure graphite crystal.

Relative conductivity in plane of carbon hexagons	Relative conductivity perpendicular to plane of carbon hexagons
3.7	0.0017

Explain why the relative electrical conductivity of graphite differs with direction.

(2)

(c) Suggest why the strength of the bond between the layers in graphite would increase if some carbon atoms were replaced with nitrogen atoms.

(2)

(d) Suggest ONE benefit of using a light activated catalyst for the new process.

(1)

(e) The liquid fuel, methanol, is made by reacting carbon monoxide with hydrogen.

Write an equation for this reaction. State symbols are **not** required.

(1)

*(f) Benzene, which is needed for the new process of breaking down carbon dioxide, can be made from coal. It is now usually made by catalytic treatment of one fraction of crude oil at temperatures of around 500 °C and 20 atmospheres pressure.

Suggest the benefits and disadvantages of breaking down carbon dioxide using benzene and the catalyst as described in the passage. You should consider

- the energy and resources needed
- the effects on the atmosphere
- whether it is a beneficial method for producing energy compared to direct use of fossil fuels.

(6)

(g) Carbon exists in forms other than graphite. Nanotubes are rolls of graphite layers, and fullerenes are cages of carbon atoms. Both nanotubes and fullerenes can trap other substances in their structures, and fullerenes can be coated with other substances.

Give ONE application of carbon nanotubes or fullerenes which exploits this behaviour.

(1)