

- (v) Describe how you would test for the presence of chloride ions in a solution of calcium chloride, giving the reagent used and an observation.

*Reagent* ..... [1]

*Observation* ..... [1]

- (vi) Calcium chloride is an ionic compound.  
Draw a dot and cross diagram for this compound, showing the outer electrons for both calcium and chlorine atoms, the outer electrons for each ion and any charges produced. [2]

- (vii) Anhydrous calcium chloride, CaCl<sub>2</sub>, can be used as a drying agent for some organic liquids. During this process, hydrated calcium chloride, CaCl<sub>2</sub>·2H<sub>2</sub>O, is formed.



*M<sub>r</sub>* 111

- In a drying process, 5.55 g of anhydrous calcium chloride, CaCl<sub>2</sub>, was used.  
Calculate how much water can be removed from the organic liquid. [2]

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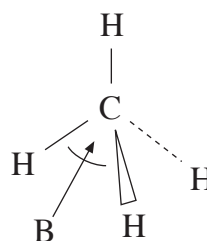
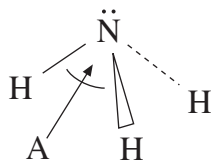
- (viii) Calcium chloride is unsuitable for drying ethanol as the ethanol bonds to the calcium chloride using a co-ordinate bond.

State what is meant by the term **co-ordinate** bond. [1]

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Total [13]

9. (a) (i) Explain why angle **A** in an ammonia molecule is less than angle **B** in a methane molecule. [1]



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- (ii) A student wrote that *'the bonds in an ammonia molecule are not purely covalent'*. Explain why this statement is correct. [2]

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(b) The d-block element, nickel, has a number of important uses.

- (i) Nickel is used as the catalyst in the hydrogenation of alkenes. Using an alkene of your choice, write an equation, using displayed formulae, for this hydrogenation, naming your product. [2]

- (ii) In recent years, nickel-containing 'smart alloys' have been developed. A particular smart alloy changes shape when a force is applied but returns to its original shape when the force is removed. Suggest a use for this type of smart alloy. [1]

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- (iii) Nickel is purified using nickel tetracarbonyl,  $\text{Ni}(\text{CO})_4$ . This is a tetrahedral molecule with the same shape as methane.

State the bond angle in such tetrahedral molecules. .... [1]

## SECTION A

Answer **all** questions in the spaces provided.

1. State which **one** of the following bonds is generally the **weakest**. [1]

A Covalent

B Hydrogen

C Ionic

D Van der Waals

.....

2. State which **one** of the following formulae represents a compound that can show hydrogen bonding. [1]

A  $\text{CH}_3\text{CH}_3$

B  $\text{CH}_3\text{OCH}_3$

C HCl

D HF

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3. Complete the table below by inserting the number of bonding pairs of electrons and name the shapes of the molecules involved. [3]

<i>Molecule</i>	<i>Number of bonding pairs of electrons in outer shell</i>	<i>Number of lone pairs of electrons in outer shell</i>	<i>Shape</i>
$\text{BeCl}_2$		0	Linear
$\text{PCl}_3$	3	1	
$\text{CCl}_4$	4	0	

## SECTION B

Answer **all** questions in the spaces provided.

7. (a) Sulfur hexafluoride, SF<sub>6</sub>, is a colourless gas that is used as an insulator in electrical transformers.

- (i) Complete the table below, giving the number of bonding and lone pairs for the sulfur atom in a molecule of gaseous sulfur hexafluoride.

Use your answers to deduce an F —  $\hat{\text{S}}$  — F angle and name the shape of the SF<sub>6</sub> molecule. [4]

Number of bonding pairs	Number of lone pairs	F — $\hat{\text{S}}$ — F	Shape

- (ii) The S — F bond in sulfur hexafluoride is a polar covalent bond. Describe what is meant by bond polarity and how it arises in this bond. [2]

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- (iii) Sulfur hexafluoride reacts with hydrogen sulfide in a redox reaction.



Complete the table below, giving the oxidation states (numbers) of the sulfur atoms present and use these to explain how hydrogen sulfide is the reducing agent in this reaction. [2]

Oxidation state of sulfur in SF <sub>6</sub>	Oxidation state of sulfur in H <sub>2</sub> S	Oxidation state of sulfur in sulfur, S

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## SECTION A

Answer **all** questions in the spaces provided.

1. (a) Ethanol is present in many intoxicating drinks. Give **one** health problem associated with the consumption of excess ethanol. [1]

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- (b) Ethanol can be converted to ethanoic acid in an oxidation reaction. Give suitable reagents for this reaction. [1]

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2. Calcium compounds are important in many biological systems. Give an example of where a calcium compound is used in a living organism. [1]

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3. State which one of the following species has the smallest bond angle. [1]



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4. Write a chemical equation for the displacement reaction that occurs when chlorine gas is bubbled through a solution of sodium bromide, NaBr. [1]

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9. Calcium oxide is one of the most widely used industrial materials in the world, with worldwide production being in the region of 283 million tonnes every year.

(a) Most calcium oxide is produced from calcium carbonate by thermal decomposition. The chemical reaction occurring is:



Calculate the atom economy of this process.

[2]

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(b) Draw a dot and cross diagram to show the formation of calcium oxide from atoms of calcium and oxygen. [2]

(c) Calcium oxide has the same crystal structure as sodium chloride.

(i) Draw the arrangement of ions in the structure of calcium oxide. [2]

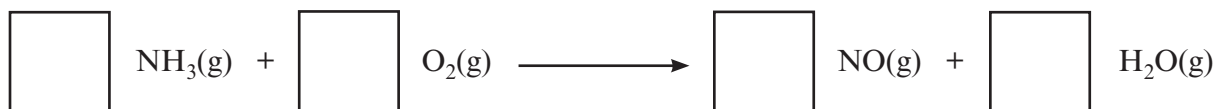
(ii) Explain why calcium chloride cannot have the same crystal structure as sodium chloride and calcium oxide. [1]

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10. Because of its many uses, over 100 million tonnes of ammonia are manufactured each year.

(a) One of the main uses of ammonia is in the production of nitric acid. In the first part of this process a mixture of ammonia and air is passed over a catalyst at 850 °C.



- (i) Balance the equation above. [1]
- (ii) Complete the table below, giving the oxidation states (numbers) of each element present and use these to explain which species has been oxidised in this reaction. [3]

Element	Initial oxidation state	Final oxidation state
nitrogen		
hydrogen		
oxygen		

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- (iii) Explain in terms of VSEPR theory why ammonia, NH<sub>3</sub>, and boron trifluoride, BF<sub>3</sub>, have different shapes. [3]

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- (b) A significant amount of ammonia is also used as a general purpose cleaner for many household surfaces.

Household ammonia is an alkaline solution formed by mixing ammonia with water.



- (i) The ammonium ion shows *coordinate bonding*. Explain what is meant by this term. [1]

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- (ii) Using outer electrons only, draw a dot and cross diagram to show the bonding in an ammonium ion. Include the charge on the ion. [2]

- (iii) State the shape of an ammonium ion and the bond angle present. [2]

*Shape* .....

*Bond angle* .....

- (iv) Another compound that contains ammonium ions is ammonium chloride,  $\text{NH}_4\text{Cl}$ . Like sodium chloride it is an ionic compound.

Explain why it is soluble in water. [2]

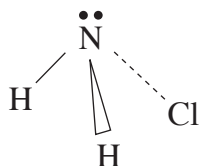
You may use a diagram in your answer.

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Total [14]



- (v) Hydrazine is manufactured from the compound monochloramine,  $\text{NH}_2\text{Cl}$ .



A probable shape for a molecule of monochloramine is as shown above. The bond angles  $\text{H}-\hat{\text{N}}-\text{H}$  and  $\text{H}-\hat{\text{N}}-\text{Cl}$  are around  $107^\circ$ .

Use the valence shell electron pair repulsion theory (VSEPR) and the information given to explain the shape and bond angles. [2]

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- (b) (i) The decomposition of hydrogen peroxide may involve hydroxyl radicals.



State why this is described as a radical. [1]

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- (ii) Another reaction that produces radicals is the reaction of chlorine with methane.

I. Give the equation for the reaction of a methyl radical and chlorine. [1]

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II. State why the reaction in I above is described as a propagation reaction. [1]

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- (b) (i) Use the VSEPR theory to deduce the shapes of  $\text{BF}_3$  and  $\text{NH}_3$ . [2]

Shape of  $\text{BF}_3$  .....

Shape of  $\text{NH}_3$  .....

- (ii) Explain the difference in the shapes of  $\text{BF}_3$  and  $\text{NH}_3$ . [2]

QWC [1]

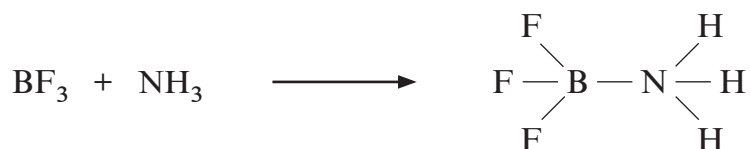
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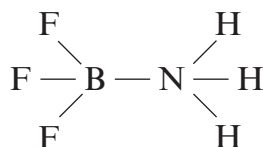
- (c) Boron fluoride reacts with ammonia,  $\text{NH}_3$ , to make the compound shown in the following equation.



- (i) Name the type of bond formed between N and B. [1]

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- (ii) Suggest a value for the F–B–F bond angle in this molecule.



Bond angle ..... [1]

- (iii) Explain your answer to part (ii). [1]

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Total [13]



10. Aluminium, boron and nitrogen all form chlorides containing three chlorine atoms,  $\text{XCl}_3$ .

(a) Molecules of boron chloride,  $\text{BCl}_3$ , and molecules of nitrogen chloride,  $\text{NCl}_3$ , have different shapes.

Use VSEPR (valence shell electron pair repulsion) theory to state and explain the shapes of these molecules.

[6]  
*QWC* [2]

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- (b) The boron atom in boron chloride,  $\text{BCl}_3$ , is described as being electron deficient. Draw a dot and cross diagram for  $\text{BCl}_3$  and use it to show what is meant by the term *electron deficient*. [2]

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- (c) Nitrogen chloride,  $\text{NCl}_3$ , is insoluble in cold water whilst the similar compound ammonia,  $\text{NH}_3$ , is very soluble. Explain this difference in behaviour. [2]

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- (d) Aluminium chloride,  $\text{AlCl}_3$ , forms a dimer that contains both covalent bonds and coordinate bonds. Describe what is meant by the terms *covalent bond* and *coordinate bond*. [2]

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Total [14]



9. (a) Petroleum is one of the most important resources in the world. It is estimated that we consume about 88 million barrels each day. Describe the general chemical composition of petroleum. [1]

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- (b) Butane is a useful fuel obtained from petroleum. Write an equation for the complete combustion of butane. [1]

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- (c) Another fuel is methane. Give the  $\text{H}-\hat{\text{C}}-\text{H}$  bond angle in a methane molecule. [1]

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- (d) Explain why the  $\text{H}-\hat{\text{O}}-\text{H}$  bond angle in water is less than the  $\text{H}-\hat{\text{C}}-\text{H}$  bond angle in methane. [3]

*QWC* [1]

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## SECTION B

Answer all questions in the spaces provided.

8. Sulfur difluoride dioxide (sulfuryl fluoride),  $\text{SO}_2\text{F}_2$ , is used as a gaseous insecticide to control termite infestations in wooden houses.

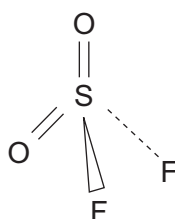
- (a) It can be produced by reacting together sulfur dioxide and fluorine.



Use the oxidation numbers of sulfur to show that sulfur has been oxidised in this reaction. In your answer you should state how changes in oxidation number are related to oxidation.

[2]

- (b) Sulfuryl fluoride is a tetrahedral molecule where the sulfur atom has no lone pairs of electrons.



Use the valence shell electron pair repulsion theory (VSEPR) to state why sulfuryl fluoride has this shape.

[1]

- (c) Ammonia reacts with sulfuryl fluoride to give sulfamide,  $\text{SO}_2(\text{NH}_2)_2$ . During this reaction ammonia reacts as a nucleophile.

- (i) State the meaning of the term *nucleophile*.

[1]

- (ii) Give the **formula** of another nucleophile.

[1]

- (iii) Organic reaction mechanisms involving nucleophiles (for example the conversion of 1-chlorobutane into butan-1-ol) often use a curly arrow ( ).

State what this curly arrow represents.

[1]

**SECTION A**

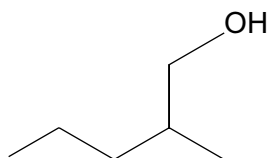
Answer **all** questions in the spaces provided.

1. Put the following in order of increasing strength. [1]

*covalent bonds*      *hydrogen bonds*      *van der Waals' forces*

*weakest* ..... *strongest*

2. Give the **systematic** name of the compound whose structure is shown below. [1]



3. Draw dot-and-cross diagrams to show the formation of calcium chloride from atoms of chlorine and calcium. [2]



6. Select **all** the molecules from the list below that have bond angles of less than  $109^\circ$ .



..... [2]

**Section A Total [10]**

