



AS level Chemistry

# CHEMICAL BONDING

MCQ

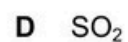
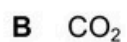
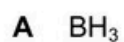
2026 EDITION

Q1

9701/11/O/N/22/Q6

Covalent Bonding - Easy

6 Which molecule has an equal number of bonding electrons and lone-pair electrons?

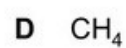
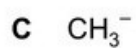
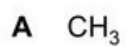


Q2

9701/12/F/M/23/Q8

Covalent Bonding - Easy

8 In which species is there a lone pair of electrons?



34 Which species can accept a lone pair of electrons to form a coordinate (dative covalent) bond?

- 1  $\text{BF}_3$
- 2  $\text{H}^+$
- 3  $\text{CH}_3^+$

The responses **A** to **D** should be selected on the basis of

| A                            | B                              | C                              | D                       |
|------------------------------|--------------------------------|--------------------------------|-------------------------|
| 1, 2 and 3<br>are<br>correct | 1 and 2<br>only are<br>correct | 2 and 3<br>only are<br>correct | 1 only<br>is<br>correct |

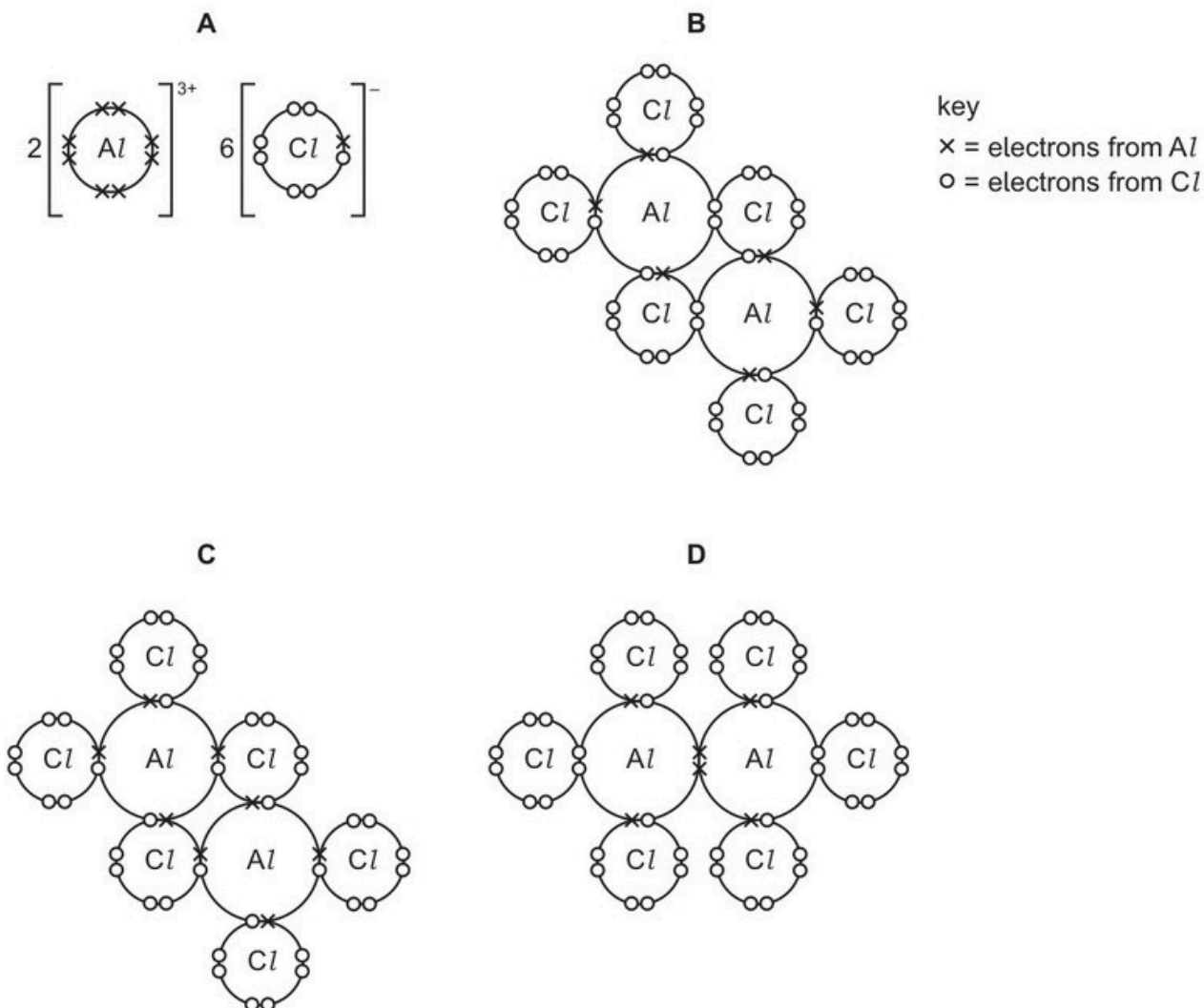
No other combination of statements is used as a correct response.

Q4

9701/12/F/M/22/Q5

Dative Bonding - Easy

5 Which dot-and-cross diagram is correct for  $Al_2Cl_6$ ?



Q5

9701/11/M/J/22/Q6

Dative Bonding - Easy

6 Which statement about aluminium chloride is correct?

- A** Aluminium chloride has a much higher melting point than magnesium chloride due to the small size of the aluminium ion.
- B** Anhydrous aluminium chloride reacts vigorously with water to form a solution with a pH greater than 7.
- C** Each  $Al_2Cl_6$  molecule found in aluminium chloride vapour contains two coordinate bonds.
- D** The bonding between aluminium and chlorine is strongly ionic due to the large difference in electronegativity.

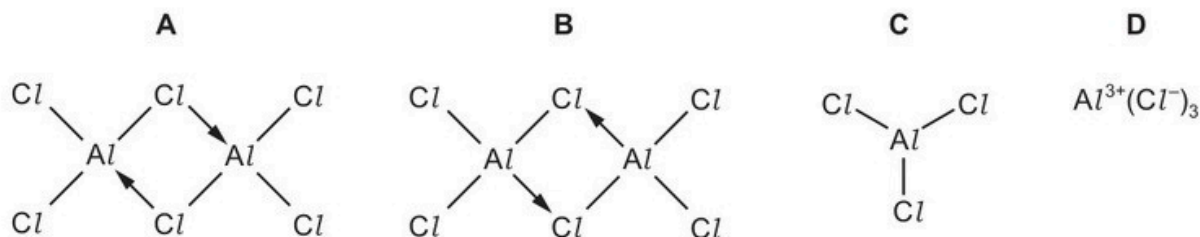
Q6

9701/11/O/N/23/Q5

Dative Bonding - Easy

- 5 Solid aluminium chloride sublimes at 178 °C.

Which structure best represents the species in the vapour at this temperature?



Q7

9701/11/M/J/24/Q5

Dative Bonding - Easy

- 5 When solid aluminium chloride is heated,  $\text{Al}_2\text{Cl}_6$  is formed.

Which bonding is present in  $\text{Al}_2\text{Cl}_6$ ?

- A** covalent and coordinate (dative covalent)  
**B** covalent only  
**C** ionic and coordinate (dative covalent)  
**D** ionic only

Q8

9701/11/O/N/24/Q5

Dative Bonding - Easy

- 5 Phosphorus forms a compound with hydrogen called phosphine,  $\text{PH}_3$ . This compound can react with a hydrogen ion,  $\text{H}^+$ .

Which type of interaction occurs between  $\text{PH}_3$  and  $\text{H}^+$ ?

- A** dative covalent bond  
**B** dipole–dipole forces  
**C** hydrogen bond  
**D** ionic bond

Q9

9701/13/O/N/24/Q5

Dative Bonding - Easy

- 5 Phosphorus forms a compound with hydrogen called phosphine,  $\text{PH}_3$ . This compound can react with a hydrogen ion,  $\text{H}^+$ .

Which type of interaction occurs between  $\text{PH}_3$  and  $\text{H}^+$ ?

- A dative covalent bond
- B dipole–dipole forces
- C hydrogen bond
- D ionic bond

Q10

9701/14/M/J/25/Q25

Dative Bonding - Easy

- 25 Which statement about an ammonium ion is correct?

- A All of the  $\text{H-N-H}$  bond angles in the ion are  $90^\circ$ .
- B All of the  $\text{H-N-H}$  bond angles in the ion are  $107^\circ$ .
- C The ion contains a  $\text{N-H}$  dative covalent bond which is weaker than the other three  $\text{N-H}$  covalent bonds.
- D The ion will react with a base as it is a weak acid.

Q11

9701/12/O/N/22/Q12

Dative Bonding - Hard

12 The compound  $(\text{CH}_3)_3\text{NAlCl}_3$  has a simple molecular structure.

Which statement about  $(\text{CH}_3)_3\text{NAlCl}_3$  is correct?

- A  $(\text{CH}_3)_3\text{NAlCl}_3$  molecules attract each other by hydrogen bonds.
- B The Al atom in  $(\text{CH}_3)_3\text{NAlCl}_3$  has an incomplete valence shell of electrons.
- C The bonds around the Al atom are planar.
- D The molecules contain coordinate bonding.

Q12

9701/12/F/M/24/Q6

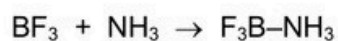
Dative Bonding - Hard

6 Aluminium chloride exists as  $\text{Al}_2\text{Cl}_6$  molecules at room temperature. When heated to a high temperature,  $\text{AlCl}_3$  molecules are formed.

What are the arrangements of the bonding pairs of electrons around the aluminium atom in the two forms of aluminium chloride?

|   | $\text{AlCl}_3$ | $\text{Al}_2\text{Cl}_6$ |
|---|-----------------|--------------------------|
| A | planar          | planar                   |
| B | planar          | tetrahedral              |
| C | tetrahedral     | tetrahedral              |
| D | tetrahedral     | octahedral               |

- 11  $\text{BF}_3$  reacts with  $\text{NH}_3$  to form a single compound with a simple molecular structure.



Which row describes how the bond angles change during the reaction?

|   | F–B–F bond angle | H–N–H bond angle |
|---|------------------|------------------|
| A | decreases        | decreases        |
| B | decreases        | increases        |
| C | increases        | decreases        |
| D | increases        | increases        |

Q14

9701/13/M/J/21/Q6

Ionic Bonding - Easy

6 Which type of bonding is **never** found in elements?

- A covalent
- B ionic
- C metallic
- D van der Waals' forces

Q15

9701/13/M/J/24/Q16

Ionic Bonding - Easy

16 Magnesium, aluminium and silicon are elements in the Periodic Table. Each element forms an oxide.

Which row is correct?

|   | MgO                        | Al <sub>2</sub> O <sub>3</sub> | SiO <sub>2</sub>       |
|---|----------------------------|--------------------------------|------------------------|
| A | basic                      | amphoteric                     | amphoteric             |
| B | giant ionic                | simple molecular               | giant ionic            |
| C | high melting point         | high melting point             | low melting point      |
| D | slight reaction with water | no reaction with water         | no reaction with water |

Q16

9701/12/O/N/24/Q8

Ionic Bonding - Easy

8 Which statement about the properties associated with the different types of bonding involved is correct?

- A Any covalent compound that contains both oxygen and hydrogen in its molecule forms hydrogen bonds.
- B Ionic bonds and covalent bonds cannot both occur in the same compound.
- C Ionic compounds differ from metals in that ionic compounds do not conduct electricity in the solid state.
- D The only covalent compounds with high melting points are those in which hydrogen bonds occur.

- 7 Substance W has the physical properties shown.

| m.p. / °C | b.p. / °C | electrical conductivity |           |           |
|-----------|-----------|-------------------------|-----------|-----------|
|           |           | of solid                | of liquid | in water  |
| 2072      | 2980      | poor                    | good      | insoluble |

What is substance W?

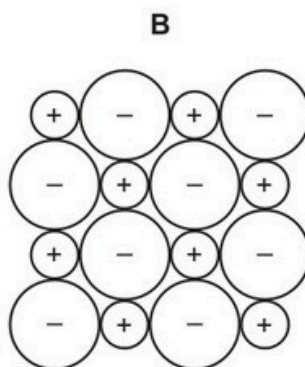
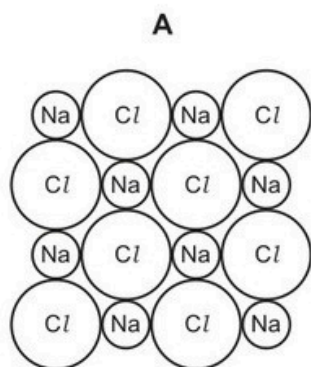
- A aluminium oxide
- B iron
- C silicon dioxide
- D sodium fluoride

Q18

9701/11/M/J/25/Q8

Ionic Bonding - Easy

8 Which diagram represents the lattice structure of sodium chloride?



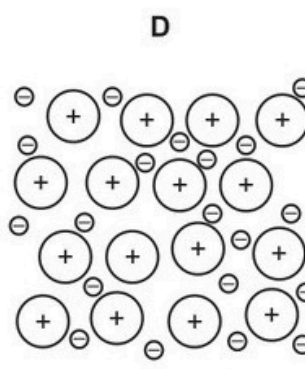
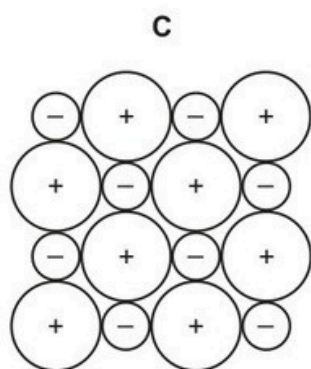
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Cl = chlorine atom

Na = sodium atom

- = chloride ion

+ = sodium ion

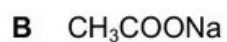
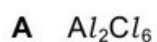


Q19

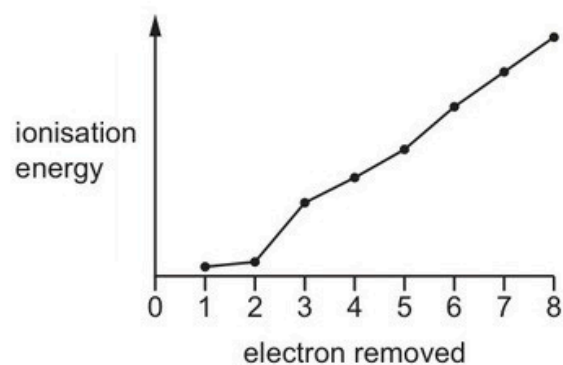
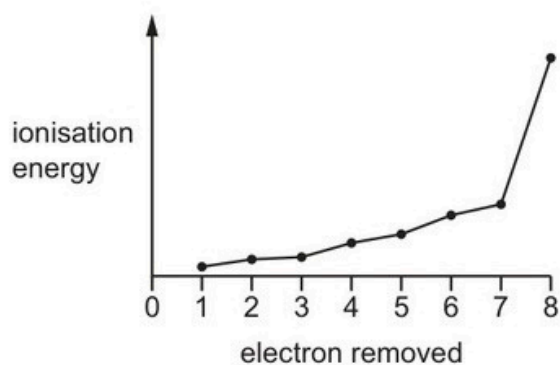
9701/14/M/J/25/Q12

Ionic Bonding - Easy

12 Which solid compound has both ionic and covalent bonding but **not** coordinate bonding?



- 3 The first eight successive ionisation energies for two elements of Period 3 of the Periodic Table are shown in the graphs.



What is the formula of the ionic compound formed from these elements?

- A**  $\text{MgCl}_2$       **B**  $\text{CaBr}_2$       **C**  $\text{Na}_2\text{S}$       **D**  $\text{K}_2\text{Se}$

Q21

9701/11/O/N/24/Q7

Metallic Bonding - Easy

- 7 The element tin exists in two forms, grey tin and white tin.

Some properties of grey tin and white tin are shown.

|                         | grey tin                | white tin                |
|-------------------------|-------------------------|--------------------------|
| boiling point / K       | 2543                    | 2533                     |
| electrical conductivity | none in solid or liquid | good in solid and liquid |
| malleability            | brittle                 | malleable                |

Which structural change might take place when grey tin changes to white tin?

- A giant covalent to giant ionic
- B giant covalent to giant metallic
- C giant ionic to giant covalent
- D giant ionic to giant metallic

Q22

9701/13/O/N/24/Q7

Metallic Bonding - Easy

- 7 The element tin exists in two forms, grey tin and white tin.

Some properties of grey tin and white tin are shown.

|                         | grey tin                | white tin                |
|-------------------------|-------------------------|--------------------------|
| boiling point / K       | 2543                    | 2533                     |
| electrical conductivity | none in solid or liquid | good in solid and liquid |
| malleability            | brittle                 | malleable                |

Which structural change might take place when grey tin changes to white tin?

- A giant covalent to giant ionic
- B giant covalent to giant metallic
- C giant ionic to giant covalent
- D giant ionic to giant metallic

- 5** Which statement explains why sodium and potassium have different melting points?
- A** The attraction between cations and delocalised electrons is stronger in sodium.
  - B** The attraction between cations and anions is stronger in sodium.
  - C** The attraction between atoms is stronger in sodium.
  - D** The attraction between nuclei and shared electron pairs is stronger in sodium.

7 Information about two substances is given.

| substance | electrical conductivity         | effect of adding to water                         | melting point / K |
|-----------|---------------------------------|---------------------------------------------------|-------------------|
| P         | good when solid and when molten | reacts vigorously to produce an alkaline solution | 454               |
| Q         | does not conduct in any state   | reacts vigorously to produce an acidic solution   | 317               |

Which row describes the structure and bonding in substances P and Q?

|   | P                | Q                |
|---|------------------|------------------|
| A | giant metallic   | simple molecular |
| B | simple molecular | giant metallic   |
| C | giant ionic      | simple molecular |
| D | giant metallic   | giant ionic      |

22 The table shows some data for the elements in Period 3 of the Periodic Table.

|            | melting point / K | electrical conductivity |
|------------|-------------------|-------------------------|
| sodium     | 371               | good                    |
| magnesium  | 922               | good                    |
| aluminium  | 933               | good                    |
| silicon    | 1693              | poor                    |
| phosphorus | 317               | does not conduct        |
| sulfur     | 386               | does not conduct        |
| chlorine   | 172               | does not conduct        |
| argon      | 84                | does not conduct        |

Which statements are correct?

- 1 All the elements in the table with a giant structure have a higher melting point than each of the elements in the table with a simple molecular structure.
- 2 Magnesium has a higher melting point than sodium because it has more delocalised electrons and stronger electrostatic attraction between the delocalised electrons and the metal ions.
- 3 Phosphorus and sulfur do **not** conduct electricity because they are simple molecular solids at room conditions.

**A** 1, 2 and 3      **B** 1 and 2 only      **C** 1 and 3 only      **D** 2 and 3 only

- 7 X and Y are different elements in Period 3.

Atoms of X and Y each have only one completely filled orbital in their highest occupied energy sub-shell.

Y has a greater first ionisation energy than X.

Which row shows the structure and bonding in X and Y?

|   | X                | Y                |
|---|------------------|------------------|
| A | giant metallic   | giant metallic   |
| B | giant metallic   | simple molecular |
| C | giant covalent   | simple molecular |
| D | simple molecular | simple molecular |

Q27

9701/11/M/J/21/Q34

VSEPR Theory - Easy

34 Which molecules contain at least one bond angle of  $120^\circ$ ?

- 1  $\text{C}_2\text{H}_4$
- 2  $\text{PF}_5$
- 3  $\text{NCl}_3$

The responses **A** to **D** should be selected on the basis of

| A                      | B                        | C                        | D                 |
|------------------------|--------------------------|--------------------------|-------------------|
| 1, 2 and 3 are correct | 1 and 2 only are correct | 2 and 3 only are correct | 1 only is correct |

No other combination of statements is used as a correct response.

Q28

9701/11/O/N/21/Q18

VSEPR Theory - Easy

18 Which row is correct?

|   | shape               |                     | bonds present    |              |
|---|---------------------|---------------------|------------------|--------------|
|   | ammonia molecule    | ammonium ion        | ammonia molecule | ammonium ion |
| A | pyramidal           | regular tetrahedral | $\sigma$         | $\sigma$     |
| B | pyramidal           | regular tetrahedral | $\sigma$         | $\pi$        |
| C | regular tetrahedral | pyramidal           | $\sigma$         | $\sigma$     |
| D | regular tetrahedral | pyramidal           | $\pi$            | $\sigma$     |

Q29

9701/12/O/N/21/Q5

VSEPR Theory - Easy

- 5 Atom X is the central atom in a molecule.

In this molecule, atom X has four pairs of valence electrons in its outer shell.

The four pairs of valence electrons include at least one bond pair and at least one lone pair.

What could be a possible shape for the molecule?

- A linear
- B non-linear
- C trigonal bipyramidal
- D trigonal planar

Q30

9701/13/O/N/21/Q18

VSEPR Theory - Easy

- 18 Which row is correct?

|   | shape               |                     | bonds present    |              |
|---|---------------------|---------------------|------------------|--------------|
|   | ammonia molecule    | ammonium ion        | ammonia molecule | ammonium ion |
| A | pyramidal           | regular tetrahedral | $\sigma$         | $\sigma$     |
| B | pyramidal           | regular tetrahedral | $\sigma$         | $\pi$        |
| C | regular tetrahedral | pyramidal           | $\sigma$         | $\sigma$     |
| D | regular tetrahedral | pyramidal           | $\pi$            | $\sigma$     |

Q31

9701/11/M/J/22/Q5

VSEPR Theory - Easy

- 5 In which structure are three atoms bonded together in a straight line?

- A poly(ethene),  $-(\text{CH}_2\text{CH}_2)_n-$
- B propane,  $\text{C}_3\text{H}_8$
- C silicon tetrachloride,  $\text{SiCl}_4$
- D sulfur hexafluoride,  $\text{SF}_6$

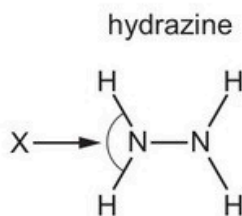
Q32

9701/13/M/J/22/Q6

VSEPR Theory - Easy

- 6 VSEPR theory should be used to answer this question.

Hydrazine has the following structure.



What is the predicted bond angle X?

- A  $90^\circ$       B  $107^\circ$       C  $109.5^\circ$       D  $120^\circ$

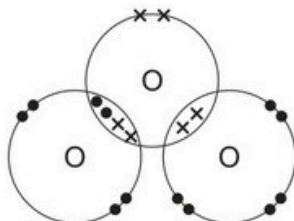
Q33

9701/12/O/N/22/Q13

VSEPR Theory - Easy

- 13 VSEPR theory should be used in answering this question.

The dot-and-cross diagram for an ozone,  $O_3$ , molecule is shown.



What is the predicted bond angle in this molecule?

- A  $107^\circ$       B  $109.5^\circ$       C  $117^\circ$       D  $120^\circ$

Q34

9701/12/M/J/23/Q7

VSEPR Theory - Easy

- 7 Which row is correct?

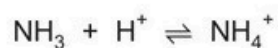
|   | molecule | shape               | total number of pairs of electrons in the valence shell of the central atom |
|---|----------|---------------------|-----------------------------------------------------------------------------|
| A | $CO_2$   | linear              | two                                                                         |
| B | $BF_3$   | trigonal planar     | three                                                                       |
| C | $NH_3$   | regular tetrahedral | four                                                                        |
| D | $PF_5$   | octahedral          | six                                                                         |

Q35

9701/13/M/J/23/Q5

VSEPR Theory - Easy

- 5 Ammonia reacts with acids to form the ammonium ion.



Which row is correct?

|   | shape of $\text{NH}_4^+$ | bond angle<br>in $\text{NH}_4^+$ / ° |
|---|--------------------------|--------------------------------------|
| A | pyramidal                | 107                                  |
| B | pyramidal                | 109.5                                |
| C | tetrahedral              | 107                                  |
| D | tetrahedral              | 109.5                                |

Q36

9701/11/O/N/23/Q6

VSEPR Theory - Easy

- 6 Which row is correct?

|   | shape of $\text{H}_3\text{O}^+$ | shape of $\text{SCl}_2$ |
|---|---------------------------------|-------------------------|
| A | pyramidal                       | non-linear              |
| B | pyramidal                       | linear                  |
| C | trigonal planar                 | non-linear              |
| D | trigonal planar                 | linear                  |

Q37

9701/12/O/N/23/Q7

VSEPR Theory - Easy

- 7 Two compounds of boron are sodium borohydride,  $\text{NaBH}_4$ , and boron trifluoride,  $\text{BF}_3$ .

What are the shapes of the borohydride ion and the boron trifluoride molecule?

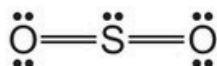
|   | borohydride ion | boron trifluoride |
|---|-----------------|-------------------|
| A | square planar   | pyramidal         |
| B | square planar   | trigonal planar   |
| C | tetrahedral     | pyramidal         |
| D | tetrahedral     | trigonal planar   |

Q38

9701/11/M/J/24/Q6

VSEPR Theory - Easy

- 6 The structure of the sulfur dioxide molecule is shown.



What is the shape of the sulfur dioxide molecule?

- A linear
- B non-linear
- C pyramidal
- D tetrahedral

Q39

9701/11/M/J/24/Q24

VSEPR Theory - Easy

- 24 What is the bond angle in the ammonium ion?

- A  $90^\circ$
- B  $107^\circ$
- C  $109.5^\circ$
- D  $120^\circ$

Q40

9701/12/M/J/24/Q5

VSEPR Theory - Easy

5 Which shape is correctly predicted by VSEPR theory?

|          | number of bonded electron pairs | number of lone pairs | shape           |
|----------|---------------------------------|----------------------|-----------------|
| <b>A</b> | 2                               | 2                    | linear          |
| <b>B</b> | 2                               | 2                    | tetrahedral     |
| <b>C</b> | 3                               | 1                    | pyramidal       |
| <b>D</b> | 3                               | 1                    | trigonal planar |

Q41

9701/12/O/N/24/Q5

VSEPR Theory - Easy

5 An ion contains 1 nitrogen atom and 2 hydrogen atoms. It has an H–N–H bond angle of approximately  $105^\circ$ .

Which row is correct?

|          | number of lone pairs around N in ion | overall charge on ion |
|----------|--------------------------------------|-----------------------|
| <b>A</b> | 1                                    | +1                    |
| <b>B</b> | 2                                    | +1                    |
| <b>C</b> | 1                                    | –1                    |
| <b>D</b> | 2                                    | –1                    |

Q42

9701/11/M/J/25/Q15

VSEPR Theory - Easy

15 In which pair do both species:

- have the same shape
- have the same number of covalent bonds?

- A** methane and the ammonium ion
- B** carbon dioxide and nitrogen
- C** boron trifluoride and ammonia
- D** water and oxygen

Q43

9701/12/M/J/25/Q7

VSEPR Theory - Easy

7 Which row is correct?

|   | smallest<br>bond angle | →                | largest<br>bond angle |
|---|------------------------|------------------|-----------------------|
| A | H <sub>2</sub> O       | NH <sub>3</sub>  | BF <sub>3</sub>       |
| B | BF <sub>3</sub>        | NH <sub>3</sub>  | H <sub>2</sub> O      |
| C | NH <sub>3</sub>        | H <sub>2</sub> O | BF <sub>3</sub>       |
| D | H <sub>2</sub> O       | BF <sub>3</sub>  | NH <sub>3</sub>       |

Q44

9701/14/M/J/25/Q11

VSEPR Theory - Easy

11 Which statement about the molecule PF<sub>5</sub> is correct?

- A Every F–P–F bond angle is 90°.
- B The central atom in the molecule does **not** have a lone pair of electrons.
- C The molecule has an overall dipole moment.
- D The shape of the molecule is octahedral.

Q45

9701/14/O/N/25/Q5

VSEPR Theory - Easy

5 In which set do all the molecules have all their atoms arranged in one plane?

- A AlCl<sub>3</sub>, BF<sub>3</sub>, PH<sub>3</sub>
- B AlCl<sub>3</sub>, CO<sub>2</sub>, NH<sub>3</sub>
- C BF<sub>3</sub>, C<sub>2</sub>H<sub>4</sub>, C<sub>3</sub>H<sub>6</sub>
- D C<sub>2</sub>H<sub>4</sub>, CO<sub>2</sub>, H<sub>2</sub>O

- 3 Phosphorus forms two chlorides. Phosphorus(III) chloride,  $\text{PCl}_3$ , is a covalent liquid.

Phosphorus(V) chloride is an ionic solid. One of the ions present is  $[\text{PCl}_4]^+$ .

What is the shape of the  $\text{PCl}_3$  molecule and the  $[\text{PCl}_4]^+$  ion?

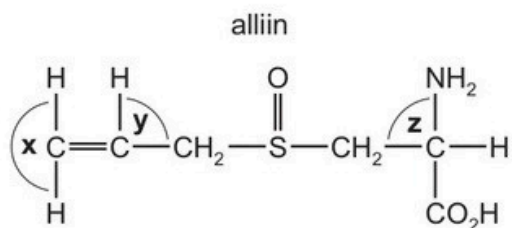
|   | $\text{PCl}_3$  | $[\text{PCl}_4]^+$ |
|---|-----------------|--------------------|
| A | pyramidal       | square planar      |
| B | pyramidal       | tetrahedral        |
| C | tetrahedral     | square planar      |
| D | trigonal planar | tetrahedral        |

Q47

9701/12/M/J/21/Q4

VSEPR Theory - Hard

- 4 The structural formula of alliin is shown.



What are the approximate bond angles **x**, **y** and **z** in a molecule of alliin?

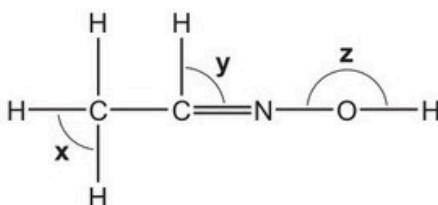
|          | <b>x</b> | <b>y</b> | <b>z</b> |
|----------|----------|----------|----------|
| <b>A</b> | 90°      | 90°      | 109°     |
| <b>B</b> | 120°     | 109°     | 90°      |
| <b>C</b> | 120°     | 120°     | 109°     |
| <b>D</b> | 180°     | 109°     | 109°     |

Q48

9701/13/M/J/21/Q4

VSEPR Theory - Hard

- 4 Ethanal reacts with hydroxylamine,  $\text{NH}_2\text{OH}$ , to form the molecule shown.



What is the order of **increasing** bond angle in this structure from smallest to largest?

- A** z, x, y      **B** y, z, x      **C** x, z, y      **D** z, y, x

Q49

9701/12/F/M/22/Q25

VSEPR Theory - Hard

- 25 When ammonia,  $\text{NH}_3$ , is dissolved in water, a small concentration of ammonium ions,  $\text{NH}_4^+$ , is formed.

Which row is correct?

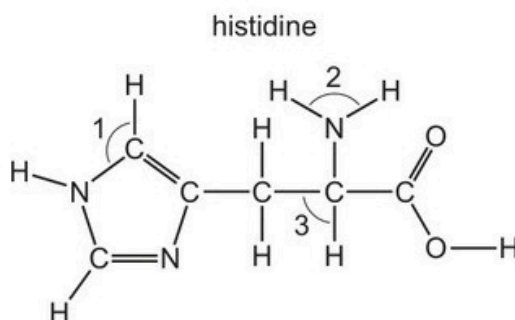
|          | number of electrons in one ammonium ion | change of the H–N–H angle from ammonia to the ammonium ion |
|----------|-----------------------------------------|------------------------------------------------------------|
| <b>A</b> | 8                                       | decreases                                                  |
| <b>B</b> | 8                                       | increases                                                  |
| <b>C</b> | 10                                      | decreases                                                  |
| <b>D</b> | 10                                      | increases                                                  |

Q50

9701/11/M/J/23/Q7

VSEPR Theory - Hard

- 7 Histidine is an amino acid.



What are the approximate bond angles 1, 2, and 3?

|          | 1      | 2    | 3      |
|----------|--------|------|--------|
| <b>A</b> | 109.5° | 107° | 90°    |
| <b>B</b> | 120°   | 107° | 109.5° |
| <b>C</b> | 120°   | 120° | 90°    |
| <b>D</b> | 120°   | 120° | 109.5° |

Q51

9701/13/M/J/24/Q5

VSEPR Theory - Hard

- 5 Arsenic forms a compound with fluorine. In this compound, the arsenic atom has no lone pair of electrons and there are no dative bonds.

Selenium also forms a compound with fluorine. In this compound, the selenium atom has no lone pair of electrons and there are no dative bonds.

In which compounds are there two different bond angles?

(In this question,  $180^\circ$  bond angles should be ignored.)

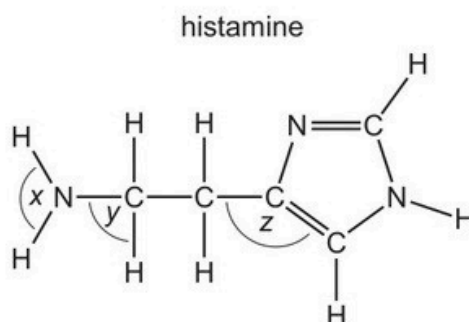
- A both arsenic fluoride and selenium fluoride  
 B arsenic fluoride only  
 C selenium fluoride only  
 D neither arsenic fluoride nor selenium fluoride

Q52

9701/12/F/M/25/Q5

VSEPR Theory - Hard

- 5 The structure of the hormone histamine is shown.

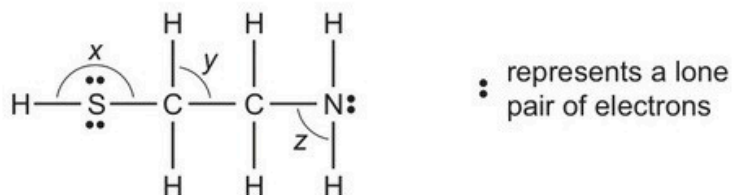


Which row contains the bond angles  $x$ ,  $y$  and  $z$  in histamine in the correct order from the smallest to the largest?

|   | smallest<br>bond angle | →   | largest<br>bond angle |
|---|------------------------|-----|-----------------------|
| A | $x$                    | $y$ | $z$                   |
| B | $y$                    | $x$ | $z$                   |
| C | $y$                    | $z$ | $x$                   |
| D | $z$                    | $y$ | $x$                   |

- 3 In which pair is the bond angle in the first species smaller than the smallest bond angle in the second species?
- A  $\text{CH}_4$  and  $\text{SF}_6$
  - B  $\text{CO}_2$  and  $\text{BF}_3$
  - C  $\text{H}_2\text{O}$  and  $\text{H}_3\text{O}^+$
  - D  $\text{NH}_4^+$  and  $\text{NH}_3$

- 6 Three bond angles are labelled on the molecule shown.



What is the order of **decreasing** size of the bond angles x, y and z?

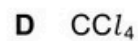
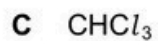
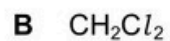
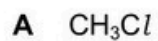
|          | largest | → | smallest |
|----------|---------|---|----------|
| <b>A</b> | x       | y | z        |
| <b>B</b> | x       | z | y        |
| <b>C</b> | y       | z | x        |
| <b>D</b> | z       | y | x        |

Q55

9701/12/F/M/22/Q4

Electronegativity - Easy

4 For which molecule is the dipole moment zero?

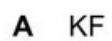


Q56

9701/13/M/J/22/Q5

Electronegativity - Easy

5 Which compound has the smallest difference in electronegativity between its two elements?



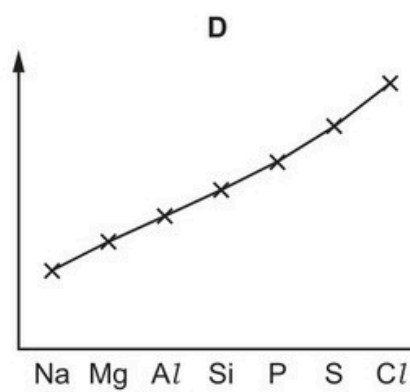
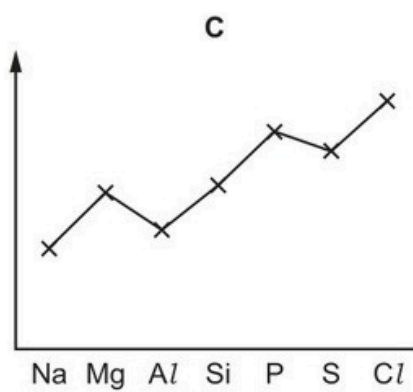
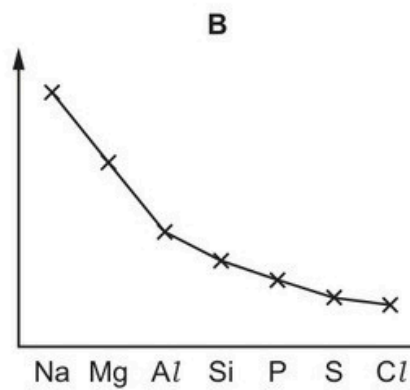
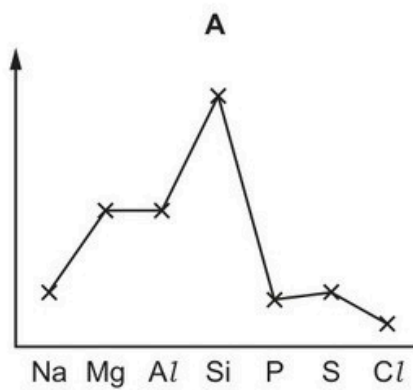
Q57

9701/13/O/N/24/Q6

Electronegativity - Easy

- 6 The graphs show trends in four physical properties of elements in Period 3, excluding argon.

Which graph has electronegativity on the y-axis?

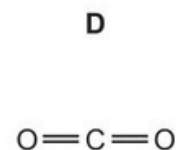
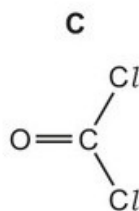
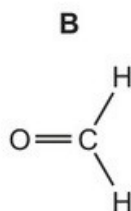
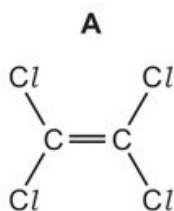


Q58

9701/12/O/N/21/Q6

Electronegativity - Hard

6 Which molecule has the largest overall dipole?



Q59

9701/13/M/J/23/Q4

Electronegativity - Hard

4 L and M are elements in Period 3 of the Periodic Table. Neither element is argon.

Information about the Pauling electronegativity values of L and M is given.

| element | Pauling electronegativity value            |
|---------|--------------------------------------------|
| L       | the highest of the seven elements Na to Cl |
| M       | the lowest of the seven elements Na to Cl  |

Three statements about elements L and M are given.

- 1 Element L contains covalent bonds.
- 2 Element L has a higher atomic number than element M.
- 3 A compound of L and M contains ionic bonds.

Which statements are correct?

- A** 1, 2 and 3      **B** 1 and 2 only      **C** 1 and 3 only      **D** 2 and 3 only

Q60

9701/12/M/J/23/Q6

Sigma Bond - Easy

6 Which statement about the  $\text{Cl}-\text{N}=\text{O}$  molecule is correct?

- A Each molecule contains one  $\sigma$  and two  $\pi$  bonds.
- B It is a non-polar molecule.
- C It is a linear molecule.
- D The nitrogen atom is  $\text{sp}^2$  hybridised .

Q61

9701/12/F/M/24/Q5

Sigma Bond - Easy

5 Which row shows the correct number of covalent bonds in a molecule of methylpropene?

|   | total number of sigma ( $\sigma$ )<br>bonds in the molecule | total number of pi ( $\pi$ )<br>bonds in the molecule |
|---|-------------------------------------------------------------|-------------------------------------------------------|
| A | 10                                                          | 1                                                     |
| B | 10                                                          | 2                                                     |
| C | 11                                                          | 1                                                     |
| D | 11                                                          | 2                                                     |

Q62

9701/12/F/M/25/Q16

Sigma Bond - Easy

16 Propene, hydrogen cyanide and carbon dioxide each contain  $\pi$  bonds.

Which molecules contain two  $\pi$  bonds?

- A carbon dioxide and hydrogen cyanide
- B carbon dioxide and propene
- C hydrogen cyanide and propene
- D hydrogen cyanide only

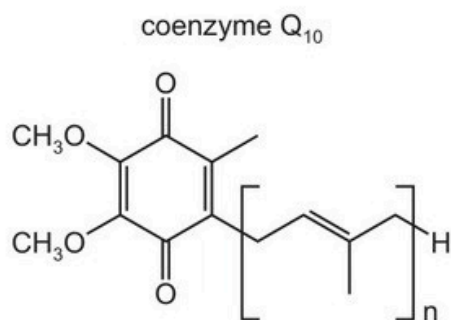
**25** Two statements about a molecule of methanal are given.

- 1 It is planar.
- 2 It contains three  $\sigma$  bonds.

Which statements are correct?

- A** both 1 and 2
- B** 1 only
- C** 2 only
- D** neither 1 nor 2

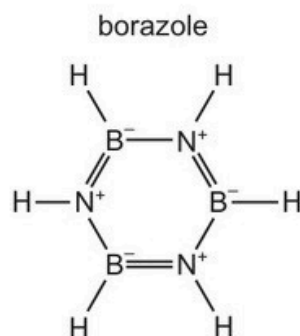
33 The diagram shows a simplified structure of coenzyme Q<sub>10</sub>.



Which row describes the structure of coenzyme Q<sub>10</sub> correctly?

|          | the coenzyme is | number of $\pi$ bonds<br>in one molecule |
|----------|-----------------|------------------------------------------|
| <b>A</b> | an aldehyde     | $n + 2$                                  |
| <b>B</b> | an aldehyde     | $n + 4$                                  |
| <b>C</b> | a ketone        | $n + 2$                                  |
| <b>D</b> | a ketone        | $n + 4$                                  |

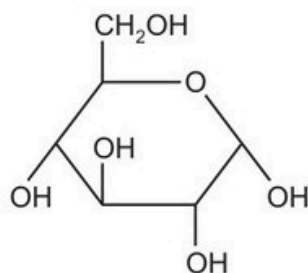
- 6 A structure for borazole,  $\text{N}_3\text{B}_3\text{H}_6$ , is shown.



Which shape is borazole and how many  $\pi$  electrons are there in the structure?

|          | shape      | number of $\pi$ electrons |
|----------|------------|---------------------------|
| <b>A</b> | non-planar | 3                         |
| <b>B</b> | non-planar | 6                         |
| <b>C</b> | planar     | 3                         |
| <b>D</b> | planar     | 6                         |

- 8 The structure of a molecule found in food is shown.



Four statements about the molecule are listed.

- 1 This molecule contains only  $\sigma$  bonds.
- 2 This molecule contains both  $\sigma$  and  $\pi$  bonds.
- 3 The six-membered ring is planar.
- 4 The six-membered ring is non-planar.

Which two statements are correct?

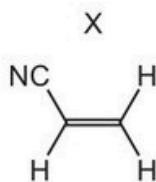
- A** 1 and 3      **B** 1 and 4      **C** 2 and 3      **D** 2 and 4

Q67

9701/11/M/J/24/Q26

Hybridisation - Easy

26 The diagram shows the structure of X.



Which row is correct?

|          | number of<br>$\sigma$ bonds in X | type of hybridisation of<br>the carbon atoms in X |
|----------|----------------------------------|---------------------------------------------------|
| <b>A</b> | 4                                | $sp$ and $sp^2$                                   |
| <b>B</b> | 4                                | $sp^2$ and $sp^3$                                 |
| <b>C</b> | 6                                | $sp$ and $sp^2$                                   |
| <b>D</b> | 6                                | $sp^2$ and $sp^3$                                 |

Q68

9701/12/F/M/25/Q39

Hybridisation - Easy

39 What is the total number of  $sp^3$  hybridised atomic orbitals used in the bonding of but-2-ene?

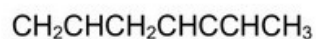
**A** 2**B** 4**C** 6**D** 8

Q69

9701/11/M/J/25/Q39

Hybridisation - Easy

39 The structural formula of hept-1,4,5-triene is shown.



How many of the carbon atoms in one molecule of hept-1,4,5-triene are  $\text{sp}^2$  hybridised?

A 4

B 5

C 6

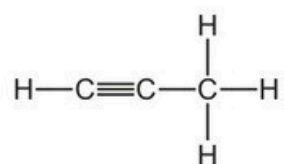
D 7

Q70

9701/14/O/N/25/Q6

Hybridisation - Easy

6 The diagram shows the bonding in a molecule of propyne.



Which types of hybridisation are shown by the carbon atoms in propyne?

A  $\text{sp}$ ,  $\text{sp}^2$  and  $\text{sp}^3$

B  $\text{sp}$  and  $\text{sp}^3$  only

C  $\text{sp}^2$  and  $\text{sp}^3$  only

D  $\text{sp}^2$  only

Q71

9701/12/O/N/23/Q5

Hybridisation - Hard

- 5 Ammonium ions,  $\text{NH}_4^+$ , are formed when ammonia gas reacts with hydrogen chloride gas.

Which statement about the changes that occur in this reaction is correct?

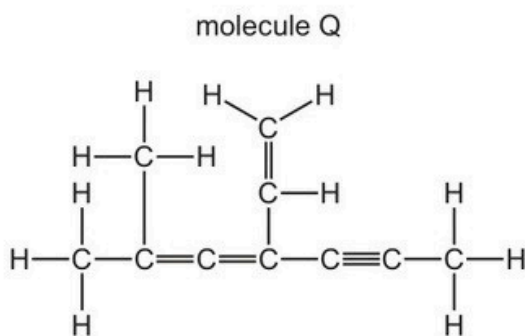
- A The dipole moment of an ammonium ion is greater than the dipole moment of an ammonia molecule.
- B The H–N–H bond angle decreases when an ammonium ion is formed.
- C The hybridisation of nitrogen does **not** change.
- D There is electron transfer from nitrogen to chlorine.

Q72

9701/12/O/N/24/Q25

Hybridisation - Hard

- 25 The diagram shows the structural formula of a hydrocarbon molecule Q.



How many of the carbon atoms in molecule Q are  $\text{sp}^2$  hybridised?

- A 3                      B 4                      C 7                      D 10

- 5 The bonding between two atoms of nitrogen in an  $\text{N}_2$  molecule involves the hybridisation of atomic orbitals to form sp orbitals.

Which row is correct?

|   | formation of the $\sigma$ bond between the nitrogen atoms in $\text{N}_2$ | type of orbital which contains the lone pair of electrons on each nitrogen atom in $\text{N}_2$ |
|---|---------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------|
| A | an sp orbital from one atom overlaps with an sp orbital of the other atom | p                                                                                               |
| B | an sp orbital from one atom overlaps with an sp orbital of the other atom | sp                                                                                              |
| C | an s orbital from one atom overlaps with a p orbital of the other atom    | p                                                                                               |
| D | an s orbital from one atom overlaps with a p orbital of the other atom    | sp                                                                                              |

Q74

9701/11/O/N/21/Q5

Intermolecular Forces - Easy

- 5 Which type of interaction exists between water molecules and metal cations in aqueous solution?
- A dipole-dipole interactions
  - B hydrogen bonds
  - C ion-dipole interactions
  - D ionic bonds

Q75

9701/11/O/N/21/Q6

Intermolecular Forces - Easy

- 6 Which substance shows the greatest deviation from the properties of an ideal gas under room conditions?
- A  $\text{CO}_2(\text{g})$       B  $\text{H}_2(\text{g})$       C  $\text{Ne}(\text{g})$       D  $\text{NH}_3(\text{g})$

Q76

9701/12/F/M/23/Q14

Intermolecular Forces - Easy

- 14 In a sample of pure water, what is the maximum number of hydrogen bonds that one molecule of water can be involved in?
- A 1      B 2      C 3      D 4

Q77

9701/12/F/M/24/Q8

Intermolecular Forces - Easy

- 8 At room temperature and pressure,  $\text{H}_2\text{O}$  is a liquid and  $\text{H}_2\text{S}$  is a gas.

What is the reason for this difference of state?

- A O has higher first and second ionisation energies than S.
- B The covalent bond between O and H is stronger than the covalent bond between S and H.
- C There is significant hydrogen bonding between  $\text{H}_2\text{O}$  molecules but **not** between  $\text{H}_2\text{S}$  molecules.
- D The instantaneous dipole-induced dipole forces between  $\text{H}_2\text{O}$  molecules are stronger than the instantaneous dipole-induced dipole forces between  $\text{H}_2\text{S}$  molecules.

Q78

9701/12/O/N/24/Q6

Intermolecular Forces - Easy

- 6 Why does  $\text{ICl}$  have a higher boiling point than  $\text{Br}_2$ ?

- A because of the difference in the bond energies of the covalent bonds within  $\text{ICl}$  and  $\text{Br}_2$
- B because of the difference in the polar nature of  $\text{ICl}$  and  $\text{Br}_2$
- C because of the difference in the number of electrons contained within  $\text{ICl}$  and  $\text{Br}_2$
- D because of the difference in the relative molecular mass of  $\text{ICl}$  and  $\text{Br}_2$

Q79

9701/12/M/J/25/Q1

Intermolecular Forces - Easy

1 Consider the following statements.

- 1 Silicon dioxide has a higher melting point than sulfur dioxide.
- 2 Ammonia has a higher boiling point than phosphine,  $\text{PH}_3$ .

Which statements are correct?

- A both statement 1 and statement 2
- B statement 1 only
- C statement 2 only
- D neither statement 1 nor statement 2

Q80

9701/14/O/N/25/Q7

Intermolecular Forces - Easy

7 The boiling point of water,  $\text{H}_2\text{O}$ , is higher than that of hydrogen sulfide,  $\text{H}_2\text{S}$ .

Which statement explains this difference in boiling points?

- A The bond energy of O–H is greater than the bond energy of S–H.
- B The intermolecular forces in  $\text{H}_2\text{O}$  are weaker than the intermolecular forces in  $\text{H}_2\text{S}$ .
- C The S–H bond in  $\text{H}_2\text{S}$  is longer than the O–H bond in  $\text{H}_2\text{O}$ .
- D There is significant intermolecular hydrogen bonding in  $\text{H}_2\text{O}$  but **not** in  $\text{H}_2\text{S}$ .

Q81

9701/13/M/J/21/Q5

Intermolecular Forces - Hard

5 Descriptions of the bonding in three substances are given.

- substance 1 strong covalent bonds between atoms, permanent dipole-dipole attractions between molecules
- substance 2 strong covalent bonds between atoms, weak forces between molecules
- substance 3 strong covalent bonds between atoms, hydrogen bonding between molecules

Which compounds could be substances 1, 2 and 3?

|          | substance 1                     | substance 2                     | substance 3                     |
|----------|---------------------------------|---------------------------------|---------------------------------|
| <b>A</b> | CH <sub>3</sub> OH              | Al <sub>2</sub> Cl <sub>6</sub> | CH <sub>2</sub> Cl <sub>2</sub> |
| <b>B</b> | Al <sub>2</sub> Cl <sub>6</sub> | CH <sub>2</sub> Cl <sub>2</sub> | CH <sub>4</sub>                 |
| <b>C</b> | CH <sub>2</sub> Cl <sub>2</sub> | CH <sub>4</sub>                 | CH <sub>3</sub> OH              |
| <b>D</b> | CH <sub>4</sub>                 | CH <sub>3</sub> OH              | H <sub>2</sub> O                |

Q82

9701/12/O/N/21/Q7

Intermolecular Forces - Hard

7 The strength of hydrogen bonding increases as the electronegativity of the element bonded to hydrogen increases.

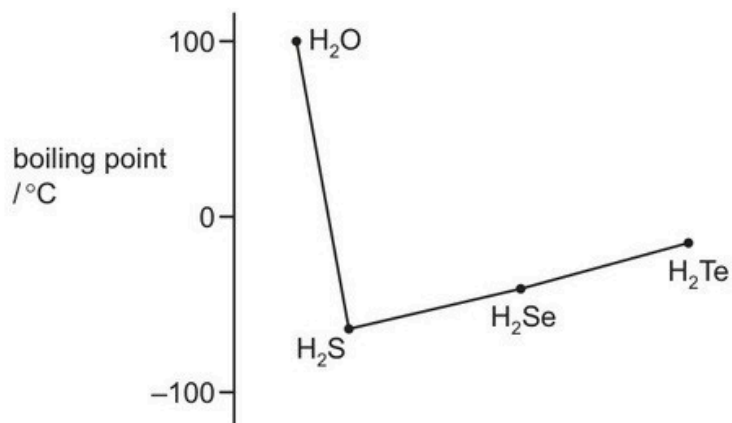
Some information for a range of hydrides is given.

| hydride          | boiling point /K |
|------------------|------------------|
| PH <sub>3</sub>  | 185              |
| HCl              | 188              |
| HF               | 293              |
| H <sub>2</sub> O | 373              |

Which statement and reason about these hydrides is correct?

- A** The boiling point of PH<sub>3</sub> is much lower than the boiling point of H<sub>2</sub>O because PH<sub>3</sub> does not form hydrogen bonds or instantaneous dipole-induced dipole forces between its molecules.
- B** The boiling point of HF is higher than the boiling point of HCl because the bond energy of H–F is greater than the bond energy of H–Cl.
- C** The boiling point of H<sub>2</sub>O is higher than the boiling point of HF because each hydrogen bond between the H<sub>2</sub>O molecules is stronger than each hydrogen bond between HF molecules.
- D** The boiling points of PH<sub>3</sub> and HCl are similar because the molecules of PH<sub>3</sub> and HCl have the same number of electrons and similar intermolecular forces.

- 8 The graph shows the boiling points of the hydrogen compounds of Group 16 elements.



Which statement correctly explains why water does **not** fit the trend of the other compounds?

- A There are fewer electrons in the oxygen atoms so there is less shielding of the nuclear charge.
- B There are strong hydrogen bonds in water but **not** in the other compounds.
- C The covalent bonds in water are much stronger than in the other compounds.
- D The water molecules are smaller and so have stronger van der Waals' forces.

Q84

9701/12/M/J/24/Q8

Intermolecular Forces - Hard

8 Consider the following four compounds.

- 1  $(\text{CH}_3)_3\text{CH}$
- 2  $\text{CH}_3\text{CH}_2\text{CH}_2\text{OH}$
- 3  $\text{CH}_3\text{CH}_2\text{CH}_2\text{SH}$
- 4  $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_3$

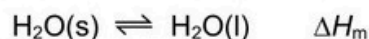
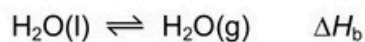
What is the order of increasing boiling point of the compounds (lowest first)?

- A** 1 → 4 → 2 → 3
- B** 1 → 4 → 3 → 2
- C** 4 → 1 → 2 → 3
- D** 4 → 1 → 3 → 2

- 10 The average intermolecular forces in water are much stronger than the average intermolecular forces in steam.

The average intermolecular forces in ice are slightly stronger than the average intermolecular forces in water.

Enthalpy changes are associated with the equilibrium processes shown.



Which statements are correct?

- 1  $\Delta H_{\text{b}}$  and  $\Delta H_{\text{m}}$  are both negative.
  - 2  $\Delta H_{\text{b}}$  is greater than  $\Delta H_{\text{m}}$ .
  - 3 The intermolecular forces in ice and water are of the same type.
- A** 1, 2 and 3      **B** 1 and 2 only      **C** 1 and 3 only      **D** 2 and 3 only

## MARKING SCHEME - COVALENT BONDING - EASY

| Q  | Ans | Paper reference   |
|----|-----|-------------------|
| Q1 | B   | 9701/11/O/N/22/Q6 |
| Q2 | C   | 9701/12/F/M/23/Q8 |

## MARKING SCHEME - DATIVE BONDING - EASY

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q3  | A   | 9701/12/F/M/21/Q34 |
| Q4  | B   | 9701/12/F/M/22/Q5  |
| Q5  | C   | 9701/11/M/J/22/Q6  |
| Q6  | A   | 9701/11/O/N/23/Q5  |
| Q7  | A   | 9701/11/M/J/24/Q5  |
| Q8  | A   | 9701/11/O/N/24/Q5  |
| Q9  | A   | 9701/13/O/N/24/Q5  |
| Q10 | D   | 9701/14/M/J/25/Q25 |

## MARKING SCHEME - DATIVE BONDING - HARD

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q11 | D   | 9701/12/O/N/22/Q12 |
| Q12 | B   | 9701/12/F/M/24/Q6  |
| Q13 | B   | 9701/13/M/J/25/Q11 |

## MARKING SCHEME - IONIC BONDING - EASY

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q14 | B   | 9701/13/M/J/21/Q6  |
| Q15 | D   | 9701/13/M/J/24/Q16 |
| Q16 | C   | 9701/12/O/N/24/Q8  |
| Q17 | A   | 9701/11/M/J/25/Q7  |
| Q18 | B   | 9701/11/M/J/25/Q8  |
| Q19 | B   | 9701/14/M/J/25/Q12 |

## MARKING SCHEME - IONIC BONDING - HARD

| Q   | Ans | Paper reference   |
|-----|-----|-------------------|
| Q20 | A   | 9701/12/M/J/24/Q3 |

## MARKING SCHEME - METALLIC BONDING - EASY

| Q   | Ans | Paper reference   |
|-----|-----|-------------------|
| Q21 | B   | 9701/11/O/N/24/Q7 |
| Q22 | B   | 9701/13/O/N/24/Q7 |
| Q23 | A   | 9701/11/O/N/25/Q5 |

## MARKING SCHEME - METALLIC BONDING - HARD

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q24 | A   | 9701/12/F/M/25/Q7  |
| Q25 | D   | 9701/11/M/J/25/Q22 |
| Q26 | B   | 9701/12/O/N/25/Q7  |

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q27 | B   | 9701/11/M/J/21/Q34 |
| Q28 | A   | 9701/11/O/N/21/Q18 |
| Q29 | B   | 9701/12/O/N/21/Q5  |
| Q30 | A   | 9701/13/O/N/21/Q18 |
| Q31 | D   | 9701/11/M/J/22/Q5  |
| Q32 | B   | 9701/13/M/J/22/Q6  |
| Q33 | C   | 9701/12/O/N/22/Q13 |
| Q34 | B   | 9701/12/M/J/23/Q7  |
| Q35 | D   | 9701/13/M/J/23/Q5  |
| Q36 | A   | 9701/11/O/N/23/Q6  |
| Q37 | D   | 9701/12/O/N/23/Q7  |

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q38 | B   | 9701/11/M/J/24/Q6  |
| Q39 | C   | 9701/11/M/J/24/Q24 |
| Q40 | C   | 9701/12/M/J/24/Q5  |
| Q41 | D   | 9701/12/O/N/24/Q5  |
| Q42 | A   | 9701/11/M/J/25/Q15 |
| Q43 | A   | 9701/12/M/J/25/Q7  |
| Q44 | B   | 9701/14/M/J/25/Q11 |
| Q45 | D   | 9701/14/O/N/25/Q5  |

## MARKING SCHEME - VSEPR THEORY - HARD

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q46 | B   | 9701/11/M/J/21/Q3  |
| Q47 | C   | 9701/12/M/J/21/Q4  |
| Q48 | A   | 9701/13/M/J/21/Q4  |
| Q49 | D   | 9701/12/F/M/22/Q25 |
| Q50 | B   | 9701/11/M/J/23/Q7  |
| Q51 | B   | 9701/13/M/J/24/Q5  |
| Q52 | A   | 9701/12/F/M/25/Q5  |
| Q53 | C   | 9701/14/M/J/25/Q3  |
| Q54 | C   | 9701/12/O/N/25/Q6  |

## MARKING SCHEME - ELECTRONEGATIVITY - EASY

| Q   | Ans | Paper reference   |
|-----|-----|-------------------|
| Q55 | D   | 9701/12/F/M/22/Q4 |
| Q56 | D   | 9701/13/M/J/22/Q5 |
| Q57 | D   | 9701/13/O/N/24/Q6 |

## MARKING SCHEME - ELECTRONEGATIVITY - HARD

| Q   | Ans | Paper reference   |
|-----|-----|-------------------|
| Q58 | B   | 9701/12/O/N/21/Q6 |
| Q59 | A   | 9701/13/M/J/23/Q4 |

## MARKING SCHEME - SIGMA BOND - EASY

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q60 | D   | 9701/12/M/J/23/Q6  |
| Q61 | C   | 9701/12/F/M/24/Q5  |
| Q62 | A   | 9701/12/F/M/25/Q16 |
| Q63 | A   | 9701/12/O/N/25/Q25 |

## MARKING SCHEME - SIGMA BOND - HARD

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q64 | D   | 9701/12/M/J/24/Q33 |
| Q65 | D   | 9701/13/M/J/24/Q6  |
| Q66 | B   | 9701/13/M/J/25/Q8  |

## MARKING SCHEME - HYBRIDISATION - EASY

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q67 | C   | 9701/11/M/J/24/Q26 |
| Q68 | D   | 9701/12/F/M/25/Q39 |
| Q69 | A   | 9701/11/M/J/25/Q39 |
| Q70 | B   | 9701/14/O/N/25/Q6  |

## MARKING SCHEME - HYBRIDISATION - HARD

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q71 | C   | 9701/12/O/N/23/Q5  |
| Q72 | B   | 9701/12/O/N/24/Q25 |
| Q73 | B   | 9701/12/O/N/25/Q5  |

## MARKING SCHEME - INTERMOLECULAR FORCES - EASY

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q74 | C   | 9701/11/O/N/21/Q5  |
| Q75 | D   | 9701/11/O/N/21/Q6  |
| Q76 | D   | 9701/12/F/M/23/Q14 |
| Q77 | C   | 9701/12/F/M/24/Q8  |
| Q78 | B   | 9701/12/O/N/24/Q6  |
| Q79 | A   | 9701/12/M/J/25/Q1  |
| Q80 | D   | 9701/14/O/N/25/Q7  |

## MARKING SCHEME - INTERMOLECULAR FORCES - HARD

| Q   | Ans | Paper reference    |
|-----|-----|--------------------|
| Q81 | C   | 9701/13/M/J/21/Q5  |
| Q82 | D   | 9701/12/O/N/21/Q7  |
| Q83 | B   | 9701/11/M/J/24/Q8  |
| Q84 | B   | 9701/12/M/J/24/Q8  |
| Q85 | D   | 9701/12/M/J/25/Q10 |
|     |     |                    |
|     |     |                    |
|     |     |                    |
|     |     |                    |