## Questions

**Q1.**

This is a question about water.

Water might be expected to have a lower boiling temperature than hydrogen sulfide but it actually has a higher boiling temperature.

Comment on this statement by referring to the intermolecular forces in both these substances.

A detailed description of how the intermolecular forces arise is not required.

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**(Total for question = 4 marks)**

**Q2.**

This question is about compounds of Group 5 elements.

Nitrogen trichloride, $NCl_3$, has a boiling temperature of 344 K, and nitrogen trifluoride, $NF_3$, has a boiling temperature of 144 K.

Explain this difference in boiling temperatures, by referring to all the intermolecular forces present.

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**(Total for question = 5 marks)**

**Q3.**

This question is about halogens and redox reactions.

The boiling temperatures of three halogens are shown in the table.

| Halogen | Boiling temperature / °C |
|---|---|
| chlorine | −35 |
| bromine | 59 |
| iodine | 184 |

Explain why the boiling temperatures increase from chlorine to iodine.

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**(Total for question = 2 marks)**

**Q4.**

* The compounds hydrogen fluoride, water and methane, all have simple molecular structures, but they have significantly different boiling temperatures.

Discuss the reasons for the differences in the boiling temperatures of the three compounds, using the data in the table and the Pauling electronegativity values in the Data Booklet.

| Compound | Boiling temperature / °C | Number of electrons |
|---|---|---|
| $CH_4$ | −161.5 | 10 |
| $H_2O$ | 100.0 | 10 |
| HF | 19.5 | 10 |

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**(Total for question = 6 marks)**

**Q5.**

This is a question about halogenoalkanes and related compounds.

Explain why ethene has a boiling temperature of −104 °C, whereas ethanol has a boiling temperature of 78 °C.

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**(Total for question = 3 marks)**

**Q6.**

This question is about the solubility of some alcohols.
The table shows the solubility in water of the first six alcohols in a homologous series.

| Alcohol | Solubility / g $dm^{-3}$ |
|---|---|
| methanol | soluble in all proportions |
| ethanol | soluble in all proportions |
| propan-1-ol | soluble in all proportions |
| butan-1-ol | 632 |
| pentan-1-ol | 22 |
| hexan-1-ol | 5.9 |

Explain why methanol and water are 'soluble in all proportions'.

You must include a diagram in your answer.

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**(Total for question = 3 marks)**

**Q7.**

This is a question about hydrocarbons.

Explain why 2,2-dimethylpropane has a much lower boiling temperature than its isomer pentane.
Detailed descriptions of the forces involved are not required.

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**(Total for question = 2 marks)**

**Q8.**

This question is about some halogens and their compounds.

The intermolecular attractions between halogen molecules are London forces.

(i) Describe how London forces form between halogen molecules.

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(ii) The boiling temperatures of chlorine and bromine are shown in the table.

| Halogen | Boiling temperature / °C |
|---|---|
| chlorine | –34 |
| bromine | 59 |

Explain why bromine has a higher boiling temperature than chlorine.

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**(Total for question = 5 marks)**

**Q9.**

Intermolecular forces affect melting temperatures, boiling temperatures and solubility.

The table gives the melting temperatures of some Group 7 hydrogen halides.

| Compound | Melting temperature / K |
|---|---|
| HF | 190 |
| HCl | 158 |
| HBr | 185 |

Predict the melting temperature, in K, of hydrogen iodide, HI, using the information in the table.

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Melting temperature of HI ..... K

**(Total for question = 1 mark)**

**Q10.**

* Methanol, $CH_3OH$, is miscible with water in all proportions.
Sodium chloride is much less soluble in methanol than in water.

Explain these statements using your knowledge of the interactions between solutes and solvents.
You **must** use diagrams to illustrate your answers.

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**(Total for question = 6 marks)**

**Q11.**

This question is about water.

Water is a polar covalent molecule. The strongest intermolecular forces between water molecules are hydrogen bonds.

(i) The O–H bond in water is polar because, when compared with the hydrogen atom, the oxygen atom has

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- ☒ **A** a higher mass number
- ☒ **B** a larger atomic radius
- ☒ **C** greater electronegativity
- ☒ **D** more electrons

(ii) Draw a diagram of a hydrogen bond between two water molecules in ice.

Show the value of the H–O–H angle within a molecule and the value of the O–H–O angle between the two molecules.

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(iii) Explain why hydrogen bonding causes ice to be less dense than liquid water.

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**(Total for question = 5 marks)**

**Q12.**

This question is about methanol, $CH_3OH$ .

Methanol is soluble in water.

(i) State the strongest type of intermolecular force that occurs between molecules of methanol and water.

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(ii) Draw a labelled diagram to show the interaction named in (i) between one molecule of methanol and one molecule of water.
Include any relevant lone pairs and dipoles in your diagram.

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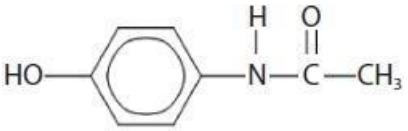
**(Total for question = 4 marks)**

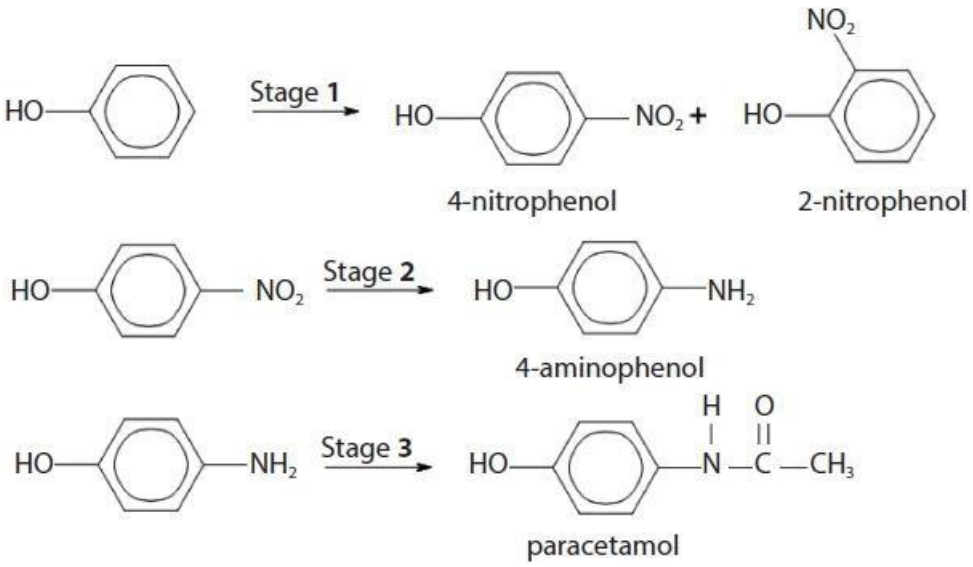
**Q13.**

This question is about the preparation and analysis of paracetamol.




paracetamol

Paracetamol may be prepared from phenol in three stages.




In Stage **1**, phenol is nitrated using dilute nitric acid.

The nitration of benzene requires concentrated nitric acid at 55°C with a catalyst of concentrated sulfuric acid.
Both these reactions are electrophilic substitution.

(i) Explain why phenol can be nitrated using milder conditions than benzene.

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(ii) A mixture of 2-nitrophenol and 4-nitrophenol is produced in Stage **1**.
They are separated by steam distillation.

The boiling temperature of 2-nitrophenol is 215°C and that of 4-nitrophenol is 279°C.
Explain, in terms of intermolecular forces, why 4-nitrophenol has a higher boiling temperature than 2-nitrophenol.
You may include a diagram in your answer.

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**(Total for question = 4 marks)**

**Q14.**

This question is about chlorine and its compounds.

In many swimming pools, sodium chlorate(I) has replaced chlorine gas as a disinfectant.

Sodium chlorate(I) is an ionic compound. It is very soluble in water.

$$NaClO(aq) \rightarrow Na^+(aq) + ClO^-(aq)$$

(i) Describe, using diagrams to illustrate your answer, the interactions between each of the ions and the solvent when sodium chlorate(I) dissolves in water.

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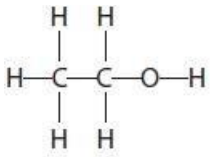
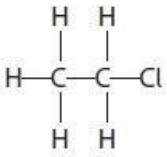
(ii) The displayed formulae of ethanol and chloroethane are shown.



ethanol



chloroethane

Ethanol is very soluble in water whereas chloroethane is almost insoluble in water. Explain this observation by comparing the types of intermolecular forces formed by each of these molecules with water.

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**(Total for question = 4 marks)**

**Q15.**

Nitrogen forms several hydrides. In addition to ammonia, $NH_3$, it forms hydrazine, $N_2H_4$, in which the two nitrogen atoms are covalently bonded together.

Hydrazine is very soluble in water.

Explain, using a labelled diagram and naming the relevant intermolecular interactions, why hydrazine is **very** soluble in water.

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**(Total for question = 3 marks)**

**Q16.**

This question is about dissolving different compounds.

* The solubility of two compounds in different solvents was investigated.
A summary of the findings is shown.

| Compound | Soluble in water | Soluble in hexane |
|---|---|---|
| 2-methylpentane | X | ✓ |
| potassium bromide | ✓ | X |

Explain the findings of the investigation by considering the interactions between the compounds and each of the solvents.

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**(Total for question = 6 marks)**

**Q17.**

This question is about structure and bonding.

* Water has two significant anomalous properties:

- it has a higher melting temperature than hydrogen sulfide, $H_2S$, even though it has fewer electrons in its molecules
- the density of ice at 0 °C is less than that of water at 0 °C.

Explain these properties.

You should include a labelled diagram to show the intermolecular forces between two molecules of water.

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**(Total for question = 6 marks)**

**Q18.**

This question is about atomic structure and the Periodic Table.

The melting temperatures of two elements in Period 3 are given in the table.

| Element | silicon | chlorine |
|---|---|---|
| Melting temperature / K | 1683 | 172 |

Explain, in terms of the structure and bonding of each element, the difference between these values.

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