Interactions

Target level
This probe is intended for students studying chemistry on post-16 courses.

Topics
Chemical bonding (including: ionic, covalent, metallic, polar, hydrogen, dipole-dipole, van der Waals, solvation, dative, double).

Rationale
Research suggests that students commonly focus on covalent and ionic bonding, and often fail to spot, or may down-play, the importance of other types of bonding.
Students may have idiosyncratic notions of the distinction between the terms 'force', 'attraction', 'bonding' and 'chemical bond'. These ideas are discussed in Chapter 8 of the Teachers' notes. This probe provides a way of exploring students' ideas about different bond types in some detail. (The probe **Spot the bonding** will provide a quicker means of auditing which bond types students can identify.)

A variety of types of diagram are used in this probe, as it is important for students to be able to interpret and use various ways of representing chemical species (see Chapter 6 of the Teachers' notes).

During piloting, this worksheet was described as a 'good probe of misconceptions' which 'hit the spot'. Students reported that the exercise made them think, and made them aware of ideas that they needed to revise.

Resources
– Student worksheets
– Interactions

Feedback for students
A generous space allowance is provided, and it should be emphasized that students do not need to fill up all the space available.
A suggested answer sheet is provided for teachers.

Interactions – answers

Classifying interactions as attraction, force, bonding or chemical bond.

In question 1: the interaction between the nucleus and the electron is an attraction, based on electrical forces, but is not usually referred to as bonding (although the term binding may sometimes be used), and is not classified as a chemical bond.

In questions 2–10: the interactions shown are examples of bonding and can be classed as chemical bonds, as well as being attractions based upon electrical forces.
(Teachers will have their own expectations about the level of detail appropriate in the responses from their groups.)

1. No specific name – intra-atomic forces or just electrical forces/electrostatic

Description – electrical attraction between positive nucleus and negative electron.

2. Covalent bond

Description – a negative pair of electrons between the two positive nuclei binds them together. Some students may discuss the formation of a (molecular) bonding orbital from the overlap of atomic orbitals.

3. **a) and b)** Ionic bond

Description – electrical attraction between each ion and the surrounding counter ions – *ie* positive cations attracted to and by surrounding negative anions – and vice versa.

4. Hydrogen bonding (and van der Waals forces and dipole-dipole forces)

Description – due to the difference in electronegativity between oxygen and hydrogen the bonds in water are polar (H δ^+ and O δ^-). Hydrogen bonding is formed when the (δ^+) hydrogen centre of one molecule is attracted to and attracts the (δ^-) oxygen centre of another. A lone pair (*ie* non-bonding pair) of electrons on one molecule attracts and is attracted by a poorly shielded proton on another molecule.

5. Solvent-solute interactions/solvation forces/hydration forces

Description – the negative poles of water molecules attract and are attracted to, the positive cations (and the positive poles of water molecules attract, and are attracted to, the negative anion).

6. Covalent bond

Description – a negative pair of electrons between the two positive cores binds them together. Some students may discuss the formation of a (molecular) bonding orbital from the overlap of atomic orbitals.

7. Van der Waals forces

Description – the synchronisation of transient fluctuating dipoles leads to induced dipole - induced dipole forces between molecules.

8. Metallic

Description – the delocalised electrons attract, and are attracted to, the positive atomic cores. (Some students may refer to the overlap of atomic orbitals to form extensive molecular orbitals – *ie* the conduction band. Other students may be aware that bonding in transition metals can be considered to have covalent character in addition to its metallic nature.)

9. Dative /co-ordinate bonding

Description – a lone pair of electrons on the chlorine centre from one molecule attracts, and is attracted by, the poorly shielded positively charged aluminium core of the other molecule – and vice versa.

10. Covalent bond

Description – a negative pair of electrons between the two adjacent positive carbon cores binds them together. Some students may discuss the formation of (molecular) bonding orbitals from the overlap of atomic orbitals.

Notes

A. At equilibrium the forces (attractions and repulsions) in molecules etc are in balance.
B. Question 3 is reproduced in two versions (3a and 3b) to allow students to demonstrate that they understand that the bonding involves the interactions between each ion each of its surrounding counter ions. Some students may class 3a as a bond, but suggest 3b (involving the same cation) must be just a force. (See Chapter 6 of theTeachers' notes.)

Interactions

This exercise is about the interactions between particles in different chemical systems (such as molecules, atoms, lattices). It has been found that different students have distinct ideas about how to label and describe the interactions that are found in chemical systems.
On each page you will find a diagram representing a chemical system (such as a single molecule, or part of a solid).

You are asked to identify and describe any interactions that are present between different parts of the chemical system in the diagram.

In each case you are asked whether you think that the interaction should be classed as an attraction, a force, bonding and/or a chemical bond. Please tick the 'yes', 'no', or 'unsure' (if you do not know) box for each of these labels. You do not have to select one and only one 'yes' answer: you may select 'no' for all four options, or 'yes' for all four, or any combination of 'yes' and 'no' responses.

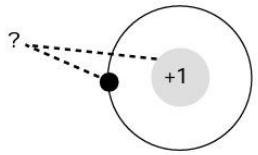
You are also asked to label the type of interaction, if you think it has a special name, and to describe the interaction as best you can in your own words. (You do not need to fill up all the lines.)

1. The diagram on the right represents a single atom of hydrogen.

Which, if any, of the following labels can be used to identify the interaction between the two parts of the system shown:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

_____
_____
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Describe this interaction in your own words. Give as much detail as you can:

_____
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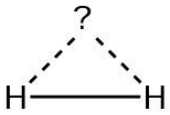
2. The diagram on the right represents a single molecule of hydrogen.
Which, if any, of the following labels can be used to identify the interaction between the two parts of the system shown:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



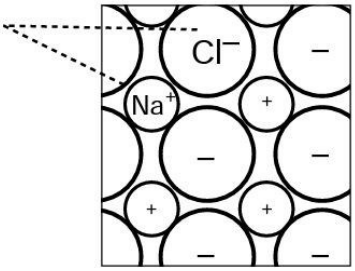
Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

Describe this interaction in your own words. Give as much detail as you can:

3a. The diagram on the right represents part of a layer in a sodium chloride lattice.
Which, if any, of the following labels can be used to identify the interaction between the two parts of the system shown:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

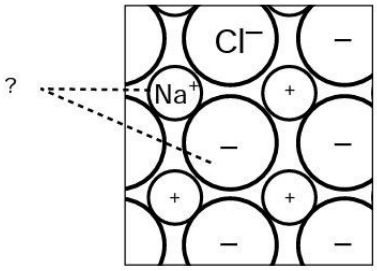
Describe this interaction in your own words. Give as much detail as you can:

3b. The diagram on the right represents the same part of a layer in a sodium chloride lattice as the previous question.

Which, if any, of the following labels can be used to identify the interaction between the two parts of the system shown:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

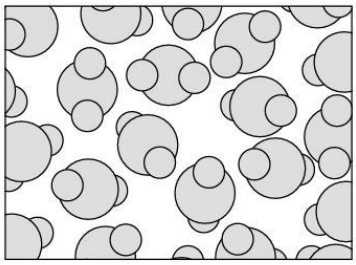
Describe this interaction in your own words. Give as much detail as you can:

4. The diagram on the right represents some water molecules in liquid water.

Which, if any, of the following labels can be used to identify the interactions between molecules in the liquid:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



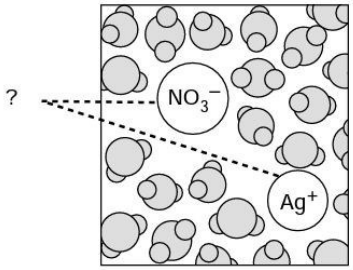
Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

Describe this interaction in your own words. Give as much detail as you can:

5. The diagram on the right represents part of an aqueous solution of silver nitrate. Which, if any, of the following labels can be used to identify the interactions between the ions and the molecules in the liquid:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



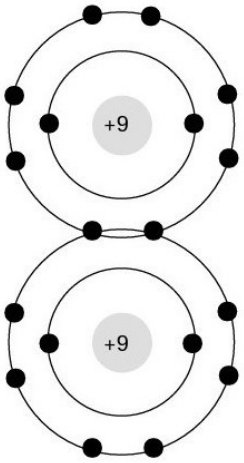
Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

Describe this interaction in your own words. Give as much detail as you can:

6. The diagram on the right represents a molecule of fluorine. Which, if any, of the following labels can be used to identify the interactions which hold the molecule together?

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



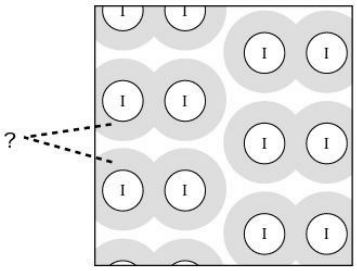
Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

Describe this interaction in your own words. Give as much detail as you can:

7. The diagram on the right represents iodine molecules in solid iodine
Which, if any, of the following labels can be used to identify the interactions between the molecules?

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



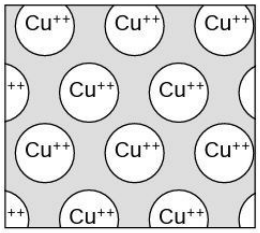
Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

Describe this interaction in your own words. Give as much detail as you can:

8. The diagram on the right represents the lattice arrangement in copper.
Which, if any, of the following labels can be used to identify the interactions holding the copper together?

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

Describe this interaction in your own words. Give as much detail as you can:

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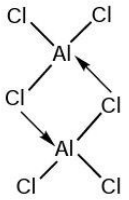
9. The diagram on the right represents a dimer of aluminium chloride ($AlCl_3$). Which, if any, of the following labels can be used to identify the interactions between the two $AlCl_3$ molecules?:

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

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Describe this interaction in your own words. Give as much detail as you can:

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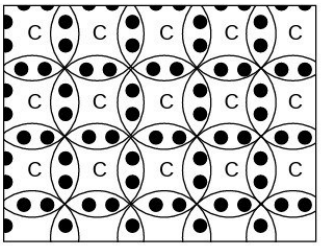
10. The diagram on the right represents part of the diamond structure of carbon. Which, if any, of the following labels can be used to identify the interactions holding the structure together?

	Yes?	No?	Unsure?
Attraction	❑	❑	❑
Force	❑	❑	❑
Bonding	❑	❑	❑
Chemical bond	❑	❑	❑

(please tick one box in each row)



Do you think this type of interaction is given a particular name/label? (If so, how would you label this type of interaction?)

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Describe this interaction in your own words. Give as much detail as you can: