Precipitation

Target level
These materials are intended for 14–16 year students who are familiar with precipitation reactions. They may also be useful for diagnosing alternative conceptions of post-16 students.

Topics
Precipitation (double decomposition) reactions; solubility; formation of ionic bonding.

Rationale
These materials were inspired by the realisation that some post-16 students were unable to explain what was happening at the level of particles when precipitation occurs. This seems to be related to research findings that suggest students may not understand what happens during dissolving, and often have alternative conceptions of the nature of ionic bonding. These ideas are discussed in the Teachers' notes. Student problems with using molecular models are considered in Chapter 6; student ideas about ionic bonding are discussed in Chapter 8; and student ideas about the precipitation process are included in Chapter 9.

The materials comprise a diagnostic probe (on the precipitation of silver chloride), a follow-up study activity and a variation on the probe (on the precipitation of lead iodide). If the materials are used after teaching, then the silver chloride probe may be used to diagnose which students would benefit from remedial action. The study activity is suitable for setting as a private study ('homework') task. The second probe may be used to see if the exercise has helped students clarify their ideas.

During piloting, teachers found that some students were confusing atoms, ions, molecules and electrons, and that the probe revealed uncertainties about the nature of ionic substances: 'they had an idea of ionic bonding that was anchored to the idea of electron transfer, which led them along a 'diatomic molecule' type approach, thinking Ag^+ was only bonded to one Cl^-'.

Teachers found the study activity valuable, but it was considered a little repetitive for some students. The diagrams were considered to be helpful. Students commented that the exercise helped them imagine what was happening during the reaction. Some found it easy, and some enjoyed colouring the key.

Details of the DARTs activity can be found in Chapter 5 of the Teachers' notes.

Instructions
The worksheet **A reaction to form silver chloride** may be used as a diagnostic probe independently of the other materials. If students are unsure of the word 'particular', they should be asked to name the atoms/molecule/ions present.
The worksheet **A precipitation reaction** provides a simple exercise taking students through the reaction described in the probe. It could be made more difficult by deleting the initial letter of the responses.
The worksheet **A reaction to form lead iodide** may be used as a post-test after the study task is completed.

Resources

_ Student worksheets
– A reaction to form silver chloride
– A precipitation reaction
– A reaction to form lead iodide
_ Coloured pencils

Feedback for students

A suggested answer sheet for each of the three activities is provided for teachers.

Precipitation – answers

A reaction to form silver chloride

1. H_2O molecules, Na^+, Cl^- ions (also allow H^+ or H_3O^+ and OH^- ions, as long as H_2O molecules given).

2. H_2O molecules, Ag^+, NO_3^- ions (also allow H^+ or H_3O^+ and OH^- ions, as long as H_2O molecules given).

3. H_2O molecules, Na^+, NO_3^- ions (also allow H^+ or H_3O^+ and OH^- ions, as long as H_2O molecules given).

   NB unless care is taken with reacting quantities the final solution may also contain either silver ions or chloride ions - but not both.

4. The important point is that the silver ions and chloride ions are already present in the mixture, and the reaction involves the electrical attraction causing the ions to clump together and form crystals.

   (Answers about ion formation through electron transfer are wrong.)

5. Students (especially those in the 14–16 age range) will not be expected to know about the precise crystal structure of silver chloride. Answers which suggest that the number of bonded ions depends upon the number of neighbours should be considered correct.

   For example, students may infer from the diagram that each ion is bonded to 4 or 6 others. Answers that are based on the charges on the ions (*ie* each silver ion is bonded to one chloride ion) are wrong, and may be related to irrelevant and inappropriate arguments about electron transfer.

A precipitation reaction

In this DART type activity (see Chapter 5 of the Teachers' notes) students have to complete missing words from the initial letters. The 'missing' words are shown here as bold text:

Sodium **chloride** is an ionic solid. Sodium ions (Na^+) and chloride ions (Cl^-) are bonded together by the **electrical** attraction between the positive and negative ions. Each **ion** is attracted to each of those counter ions surrounding it.
This type of chemical **bonding** is called ionic bonding.

Sodium chloride dissolves in water. **Water** is a liquid containing water molecules. The **molecules** move around quickly, bumping into each other. In these **collisions** the water molecules bounce off one another. Many ionic solids will **dissolve** in water.

When the sodium chloride dissolves it forms a **solution**. The solution contains the water molecules, and the **sodium** ions and the **chloride** ions from the sodium chloride. The fast **moving** water molecules constantly collide with the ions, and crowd around ('solvate') them, so that the **ions** can not stick together.

Silver nitrate is an **ionic** solid. Silver ions (Ag^+) and **nitrate** ions (NO_3^-) are bonded together by the electrical **attraction** between the **positive** and negative ions. Each ion is attracted to each of those surrounding it. This type of **chemical** bonding is called ionic bonding.

When the silver nitrate **dissolves** it forms a solution. The solution contains the water **molecules**, and the silver ions and the nitrate **ions** from the silver nitrate. The **fast** moving water molecules constantly **collide** with the ions, and crowd around ('**solvate**') them, so that the ions can not stick together.

In the mixture there would be:
water molecules, sodium cations, chloride anions, silver cations and nitrate anions

When the two solutions are **mixed** together the new mixture contains water **molecules**, sodium ions, **silver** ions, chloride ions and nitrate **ions**.

When silver ions collide with **chloride** ions they sometimes stick together. The **attraction** between these ions is so strong that collisions with the fast moving **water** molecules do not stop them bonding together.

The silver ions and **chloride** ions soon form into large enough crystals to **precipitate** out from the solution. The solid precipitate of silver chloride sinks to the **bottom** of the mixture.

In the **precipitate** silver ions (Ag^+) and chloride ions (Cl^-) are **bonded** together by the electrical attraction between the positive and negative **ions**. Each ion is attracted to **each** of those surrounding it. Silver chloride is an example of a compound with ionic bonding which does not dissolve in water (it is insoluble in **water**).

The liquid above the precipitate contains the water **molecules**, sodium ions and nitrate ions. This is a solution of sodium **nitrate**. The fast moving water molecules constantly collide with the ions, and crowd around ('solvate') them, so that the ions can not **stick** together.

The real change during the reaction is that **solvated** silver ions and solvated **chloride** ions form solid **silver** chloride:

The sodium ion and the nitrate ion (in the box at the bottom of the page) should be labelled as 'spectator ions'.

Summary sheet

Four different colours should be used to shade the four ions in the key (at foot of page). The ions in the other 5 figures should be coloured using the same colour code to show that the ions have effectively 'swapped partners'.

(It may be useful to make an overhead transparency of this page, and colour the ions. In this case the teacher may wish to set the colour code for the different ions – *eg* Na^+ blue, Ag^+ green, Cl^- yellow, NO_3^- red – so that each student can readily check their summary sheet against the version displayed on the overhead projector).

A reaction to form lead iodide

1. H_2O molecules, K^+, I^- ions (also allow H^+ or H_3O^+ ions and OH^- ions, as long as H_2O molecule is given).

2. H_2O molecules, Pb^{2+}, NO_3^- ions (also allow H^+ or H_3O^+ ions and OH^- ions, as long as H_2O molecule is given).

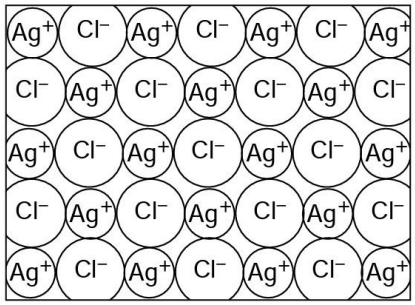
3. H_2O molecules, K^+, NO_3^- ions (also allow H^+ or H_3O^+ ions and OH^- ions, as long as H_2O molecule is given).

4. The lead ions and nitrate ions are already present in the mixture, and the reaction involves the electrical attraction causing the ions to clump together and form crystals.

5. Any answer that suggests that the number of bonded ions depends on the number of neighbours should be marked correct. Answers that are based on the charges of the ions are wrong.

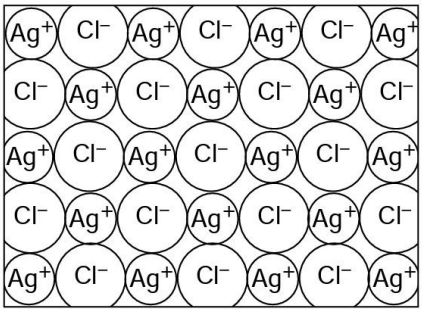
A reaction to form silver chloride

Silver chloride is an ionic solid. It can be prepared by reacting silver nitrate solution and sodium chloride solution. The diagrams represent the types of particles present in some of the substances involved in the reaction.



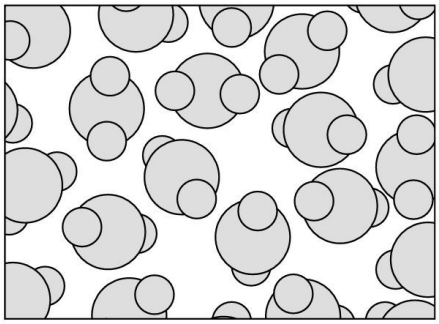
Silver nitrate (solid)

The diagram above shows the particles in solid silver nitrate. The particles in silver nitrate are silver ions (Ag^+) and nitrate ions (NO_3^-).



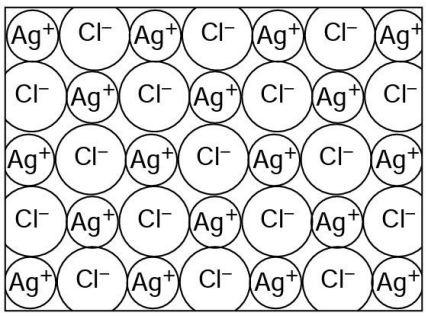
Silver chloride (solid)

The diagram above shows the particles in solid sodium chloride. The particles in sodium chloride are sodium ions (Na^+) and chloride ions (Cl^-).



Water (liquid)

The diagram above shows the particles in water. Water is a liquid. The particles are water molecules.



Silver chloride (solid)

The diagram above shows the particles in solid silver chloride. The particles in silver chloride are silver ions (Ag^+) and chloride ions (Cl^-).

A reaction to form silver chloride

The diagrams (on the other sheet) may help you with these questions.

1. Sodium chloride dissolves in water to give sodium chloride solution. What particles (such as particular atoms, molecules, ions) do you think are present in sodium chloride solution?

2. Silver nitrate dissolves in water to give silver nitrate solution. What particles (such as particular atoms, molecules, ions) do you think are present in silver nitrate solution?

When sodium chloride solution is mixed with silver nitrate solution a white solid forms. The following reaction take place:

sodium chloride(aq) + silver nitrate(aq) → sodium nitrate(aq) + silver chloride(s)

The solid that is formed is silver chloride. The solid can be separated from the liquid by filtration. The liquid that is left after filtration contains sodium nitrate.

3. What particles (such as particular atoms, molecules, ions) do you think are present in the liquid after it is filtered?

4. What do you think happens to the particles in the mixture when the ionic bonds form in the silver chloride in this reaction?

5. How many chloride ions do you think are bonded to each silver ion in silver chloride? (Give the reason for your answer, if you can.)

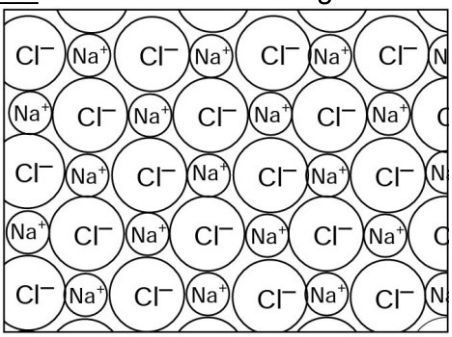
A precipitation reaction

This exercise is about what happens during a precipitation reaction. When solutions of sodium chloride and silver nitrate are mixed, then a white solid (silver chloride) forms:

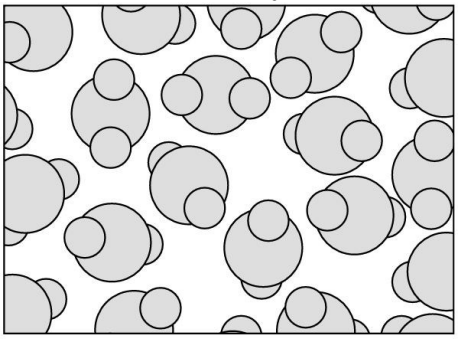
sodium chloride(aq) + silver nitrate(aq) → sodium nitrate(aq) + silver chloride(s)

Fill in the gaps below. Use the diagrams to help you.

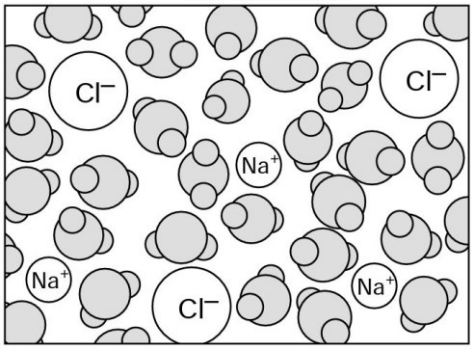
Sodium c_____ is an ionic solid. Sodium ions (Na+) and chloride ions (Cl–) are bonded together by the e_____ attraction between the positive and negative ions. Each i_____ is attracted to each of those counter ions surrounding it. This type of chemical b_____ is called ionic bonding.



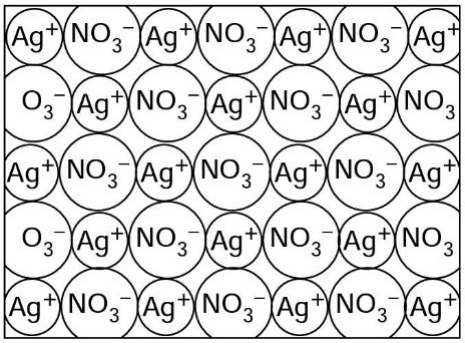
Sodium chloride dissolves in water. W_____ is a liquid containing water molecules. The m_____ move around quickly, bumping into each other. In these c_____ the water molecules bounce off one another. Many ionic solids will d_____ in water.



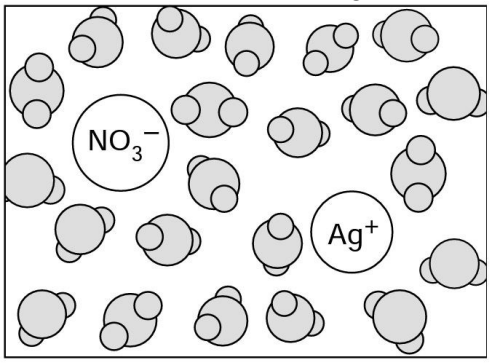
When the sodium chloride dissolves it forms a s_____. The solution contains the water molecules, and the s_____ ions and the c_____ ions from the sodium chloride. The fast m_____ water molecules constantly collide with the ions, and crowd around ('solvate') them, so that the i_____ can not stick together.



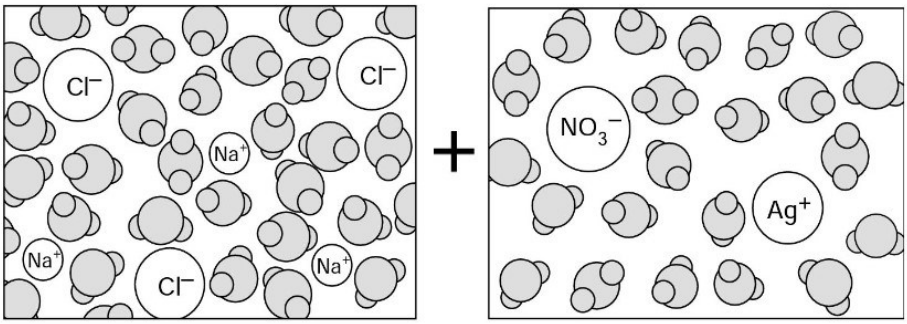
Silver nitrate is an i_____ solid. Silver ions (Ag^+) and n_____ ions (NO_3^-) are bonded together by the electrical a_____ between the p_____ and negative ions. Each ion is attracted to each of those surrounding it. This type of c_____ bonding is called ionic bonding.



When the silver nitrate d_____ it forms a solution. The solution contains the water m_____, and the silver ions and the nitrate i_____ from the silver nitrate. The f_____ moving water molecules constantly c_____ with the ions, and crowd around ('s_____') them, so that the ions can not stick together.



What do you think would be in the mixture if the two solutions below were to be poured into the same beaker?



_____

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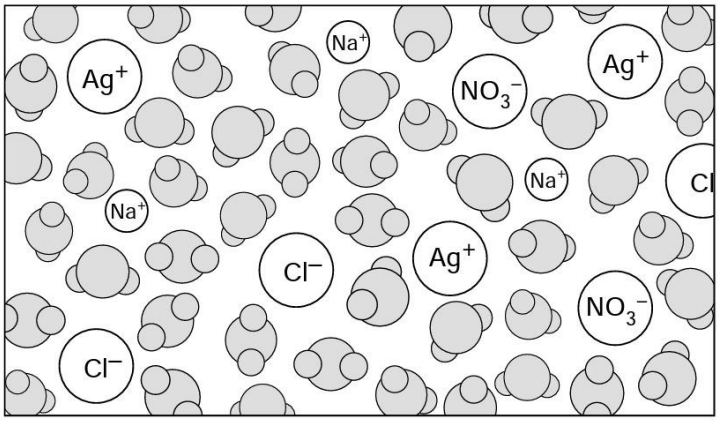
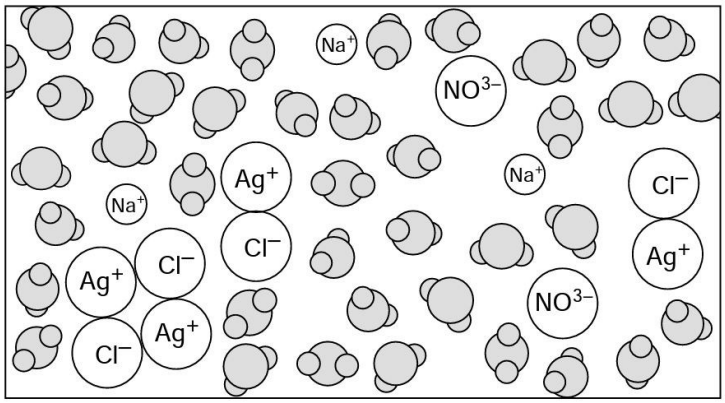
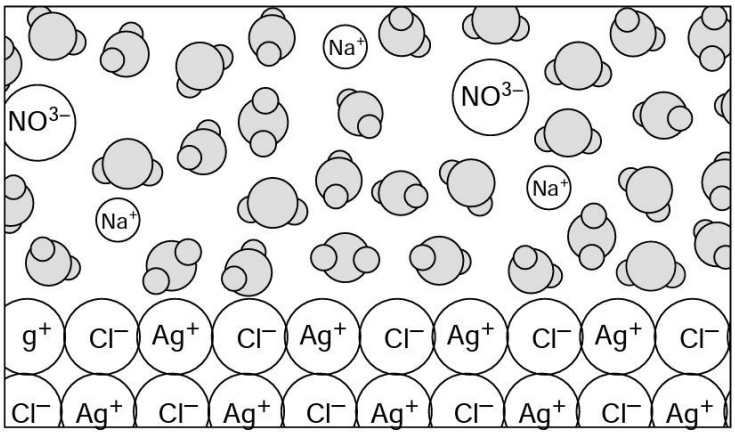
When the two solutions are m_____ together the new mixture contains water m_____, sodium ions, s_____ ions, chloride ions and nitrate i_____.



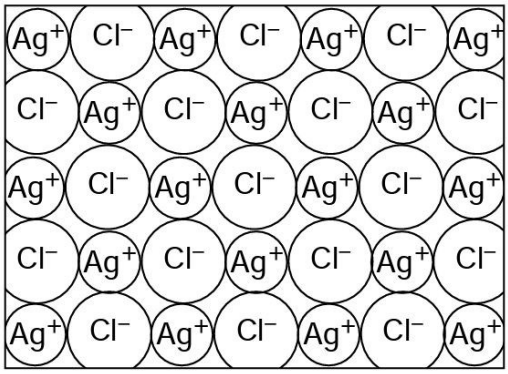
When silver ions collide with c_____ ions they sometimes stick together. The a_____ between these ions is so strong that collisions with the fast moving w_____ molecules do not stop them bonding together.



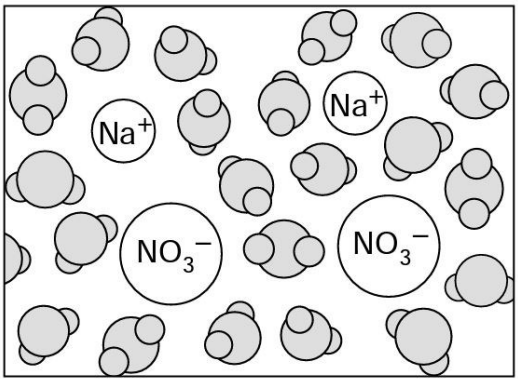
The silver ions and c_____ ions soon form into large enough crystals to p_____ out from the solution. The solid precipitate of silver chloride sinks to the b_____ of the mixture.



In the p_____ silver ions (Ag+) and chloride ions (Cl–) are b_____ together by the electrical attraction between the positive and negative i_____. Each ion is attracted to e_____ of those surrounding it. Silver chloride is an example of a compound with ionic bonding which does not dissolve in water (it is insoluble in w_____).



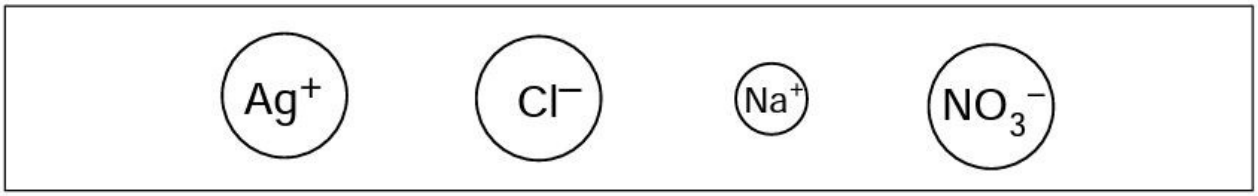
The liquid above the precipitate contains the water m_____, sodium ions and nitrate ions. This is a solution of sodium n_____. The fast moving water molecules constantly collide with the ions, and crowd around ('solvate') them, so that the ions can not s_____ together.



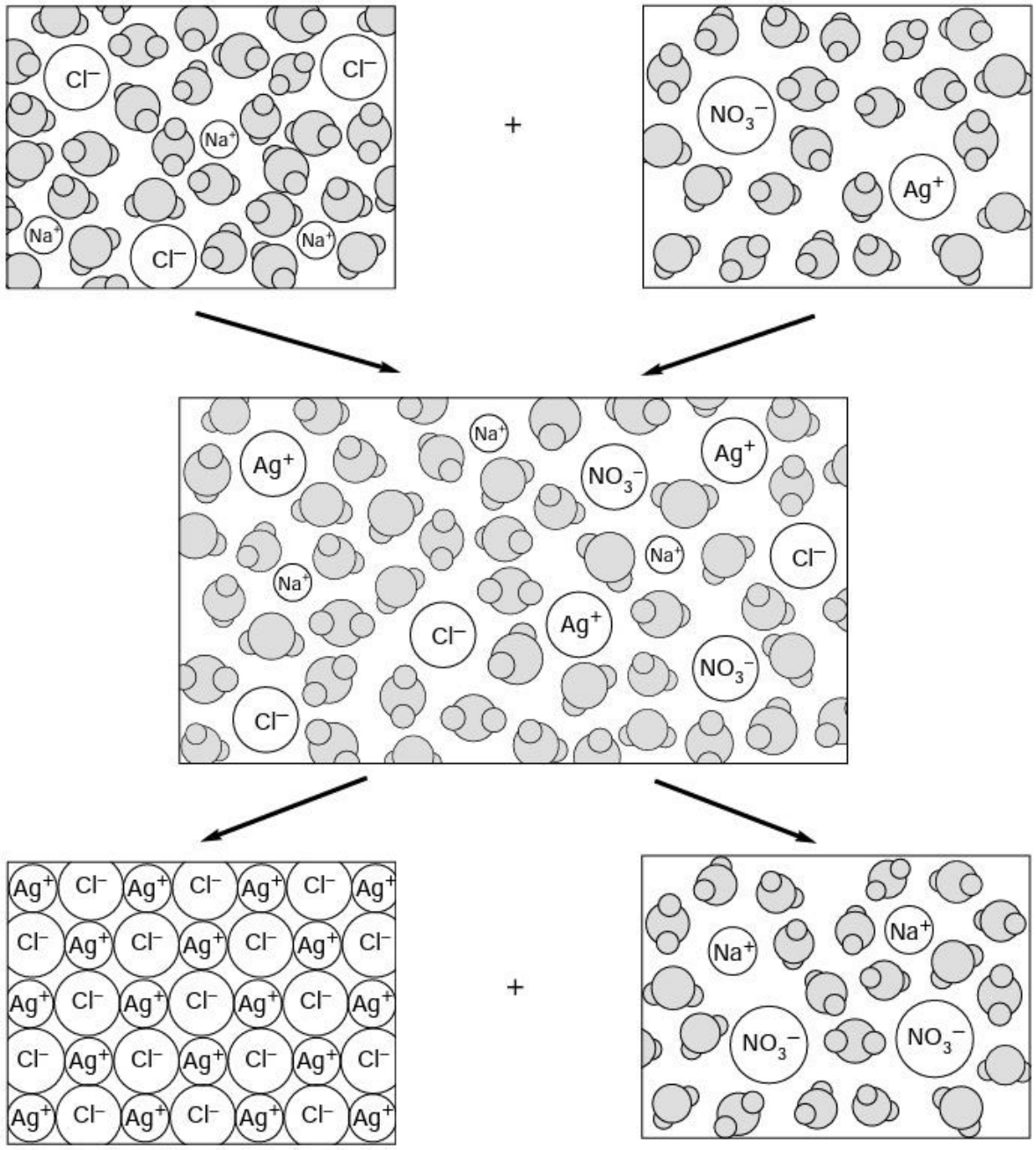
The real change during the reaction is that s_____ silver ions and solvated c_____ ions form solid s_____ chloride:

$$Cl^-(aq) + Ag^+(aq) \rightarrow AgCl(s)$$

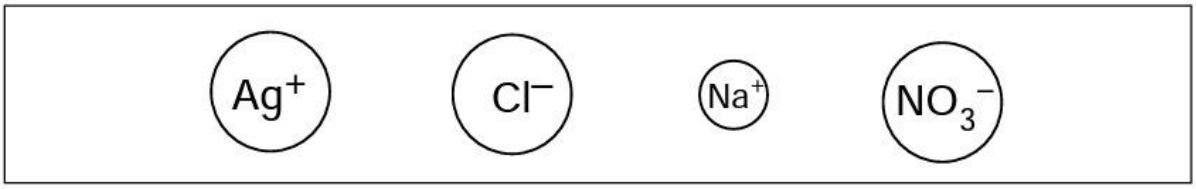
The sodium ions and nitrate ions are sometimes called 'spectator' ions because they are not directly involved in forming the product. Label the spectator ions in the box below:



Summary sheet



The change that has taken place in this reaction is more obvious if you use a colour key for the ions.
Select four different colours (*eg* blue, green, red and yellow), and colour each different type of ion in a different colour. Use the box below as a key.



A reaction to form lead iodide

Lead iodide is an ionic solid. It can be prepared by reacting lead nitrate solution and potassium iodide solution.

1. Potassium iodide dissolves in water to give potassium iodide solution. What particles (such as particular atoms, molecules, ions) do you think are present in potassium iodide solution?

2. Lead nitrate dissolves in water to give lead nitrate solution. What particles (such as particular atoms, molecules, ions) do you think are present in lead nitrate solution?

When potassium iodide solution is mixed with lead nitrate solution a yellow solid forms. The following reaction take place:

potassium iodide(aq) + lead nitrate(aq) → potassium nitrate(aq) + lead iodide(s)

The solid that is formed is lead iodide. The solid can be separated from the liquid by filtration. The liquid that is left after filtration contains potassium nitrate.

3. What particles (such as particular atoms, molecules, ions) do you think are present in the liquid after it is filtered?

4. What do you think happens to the particles in the mixture, when the ionic bond forms in the lead iodide in this reaction?

5. How many iodide ions do you think might be bonded to each lead ion in lead iodide? (Give the reason for your answer, if you can.)