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VCE Chemistry ½
Solubility & Precipitation [1.9]
Workbook

Outline:

Learning Objectives:

- ☐ **CH12 [1.9.1]** - Explain the process by which ionic compounds dissolve in water with reference to ion-dipole bonding
- ☐ **CH12 [1.9.2]** - Write balanced equations for ionic compounds dissociating/ionising in water
- ☐ **CH12 [1.9.3]** - Identify which compounds will or will not dissolve in water, with reference to SNAPE and/or solubility tables
- ☐ **CH12 [1.9.4]** - Write full & ionic equations for precipitation reactions

Section A: Dissolution

Sub-Section: Ion-Dipole Bonds

Databook: Cations and Anions

- The polyatomic ions which are tested are found on **Pages 6 and 7** of the Databook, and are shown below:

Cations

1+		2+		3+	
Name	**Formula**	**Name**	**Formula**	**Name**	**Formula**
ammonium	NH_4^+	barium	Ba^{2+}	aluminium	Al^{3+}
copper(I)	Cu^+	calcium	Ca^{2+}	chromium(III)	Cr^{3+}
hydronium	H_3O^+	copper(II)	Cu^{2+}	iron(III)	Fe^{3+}
lithium	Li^+	iron(II)	Fe^{2+}	**4+**	
potassium	K^+	lead(II)	Pb^{2+}	titanium(IV)	Ti^{4+}
silver	Ag^+	magnesium	Mg^{2+}		
sodium	Na^+	mercury(II)	Hg^{2+}		
		nickel(II)	Ni^{2+}		
		tin(II)	Sn^{2+}		
		zinc	Zn^{2+}		

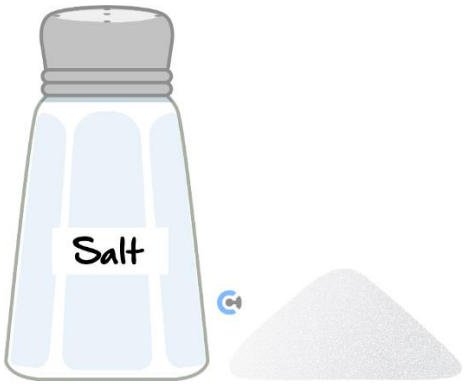
Anions

1–		2–		3–	
Name	**Formula**	**Name**	**Formula**	**Name**	**Formula**
bromide	Br^-	carbonate	CO_3^{2-}	citrate	$C_6H_5O_7^{3-}$
chlorate	ClO_3^-	chromate	CrO_4^{2-}	nitride	N^{3-}
chloride	Cl^-	dichromate	$Cr_2O_7^{2-}$	phosphate	PO_4^{3-}
chlorite	ClO_2^-	monohydrogen phosphate	HPO_4^{2-}		
cyanide	CN^-	oxide	O^{2-}		
dihydrogen phosphate	$H_2PO_4^-$	peroxide	O_2^{2-}		
ethanoate	CH_3COO^-	sulfate	SO_4^{2-}		
fluoride	F^-	sulfide	S^{2-}		
hydrogen carbonate	HCO_3^-	sulfite	SO_3^{2-}		
hydrogen sulfate	HSO_4^-	thiosulfate	$S_2O_3^{2-}$		
hydrogen sulfide	HS^-				
hydrogen sulfite	HSO_3^-				
hydroxide	OH^-				
hypochlorite	ClO^-				
iodide	I^-				
nitrate	NO_3^-				
nitrite	NO_2^-				
perchlorate	ClO_4^-				
permanganate	MnO_4^-				

Space for Personal Notes

Discussion

- Consider the ionic compound, sodium chloride ($NaCl$) which is also known as table salt.



- What happens if we place salt in a glass of water and mix thoroughly?

It 'disappears' and dissolves.

How does this happen?

Exploration: Bonding in Water

- Reconsider the structure of water (H_2O):
  - **Polarity of Water:** *(Label Below)*
  - **Intermolecular Bonding:** *(Label Below)*

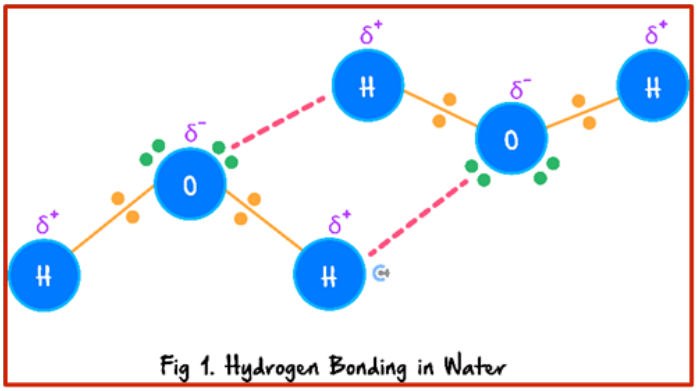


Fig 1. Hydrogen Bonding in Water

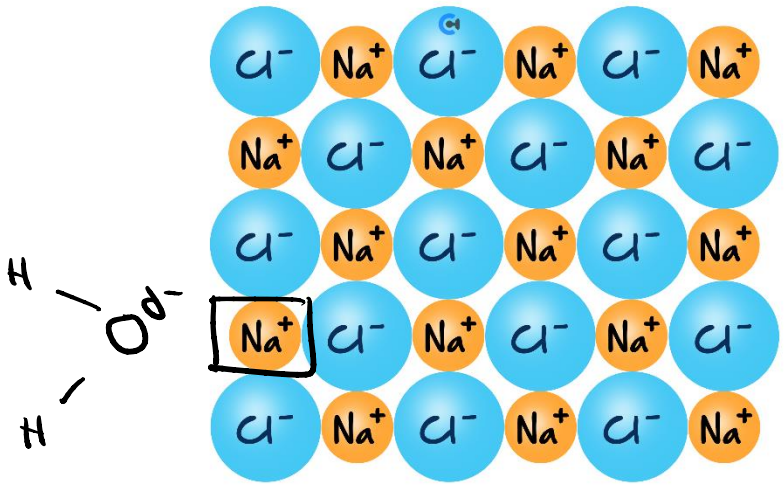
- **Type of Bonding in Water:** hydrogen bonding.

Active Recall: What type of bonding exists in sodium chloride?

Ionic

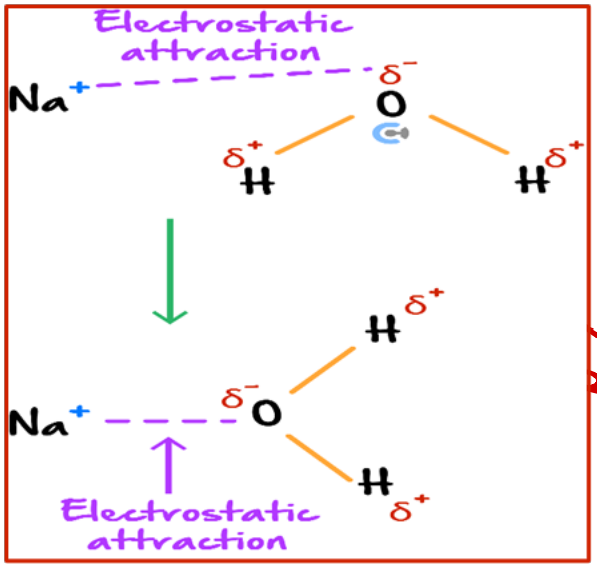
Exploration: Sodium chloride ($NaCl$) in water

- Reconsider the structure of sodium chloride ($NaCl$):

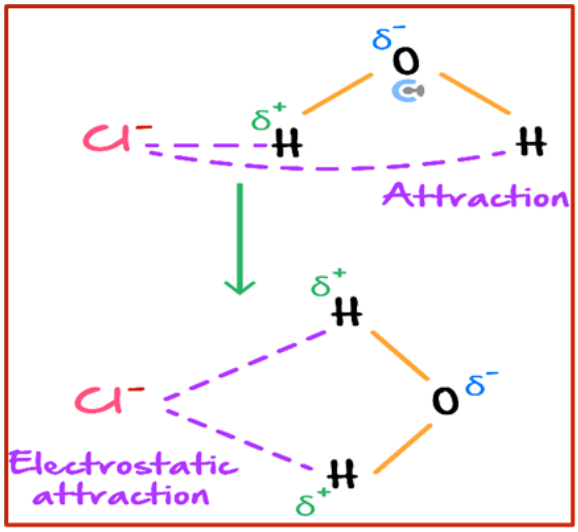


- Electrostatic Attraction: [Full]/[Partial]
- Consider a sodium ion (Na^+) next to a water molecule:
  - Attracted end of water molecule: [Positive]/[Negative]
  - Atom has this charge?: [Oxygen]/[Hydrogen]
  - Attractive force between water molecule and sodium ion? *(Label Below)*

- Water orientation for optimal attraction: *(Label Below)*



- There is electrostatic attraction between the fully positive sodium cation (Na^+) and the partially negative oxygen end of the water.
- Consider a water molecule close to a chloride ion (Cl^-):
  - What end of the water molecule would Cl^- be attracted to? [Positive]/[Negative]
  - Which atom has this charge? [Oxygen]/[Hydrogen]
  - What attractive force would exist between a water molecule and a chloride ion? *(Label Below)*
  - How might the water orient itself to optimise this attraction? *(Label Below)*

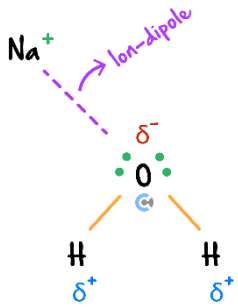


- As this electrostatic attraction occurs between a fully charged ion and a partially charged dipole, the electrostatic attraction is known as an ion–dipole bond.

Ion-dipole Bonding

Definition: The electrostatic attraction formed between a fully charged [ion]/[dipole] and a [fully]/[partially] charged dipole.

- **Definition**: The electrostatic attraction formed between a fully charged [ion]/[dipole] and a [fully]/[partially] charged dipole.
- **Occurrence**: When ionic compounds bond with water whilst dissolving.



Try a question!

Question 1

Select the correct alternative from the following:

A. Ca^{2+} would be attracted to $\delta+$ within a water molecule.

B. Only NaCl can form ion-dipole bonds.

C. Ion-dipole bonds can only be formed with water.

D. Dissolving chemicals involves the formation of ion-dipole bonds.

Question 2

Select the false alternative from the following:

A. Water ~~does not~~ exhibit dispersion forces.

B. Water has hydrogen bonding, which can be classified as a type of dipole-dipole bonding.

C. All ionic compounds can dissolve in water.

D. Electrostatic attraction is not only between cations and anions.

Sub-Section: Strength of Bonds

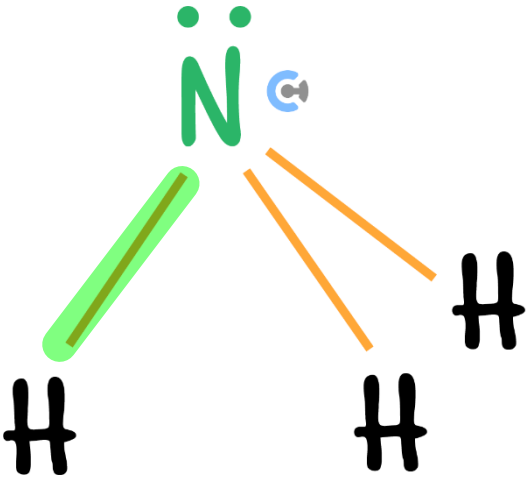
Recall!

Active Recall: What is the difference between intermolecular and intramolecular bonds?

- Intermolecular bonds are bonds which occur _____ molecules.
- Intramolecular bonds are bonds which occur _____ molecules.

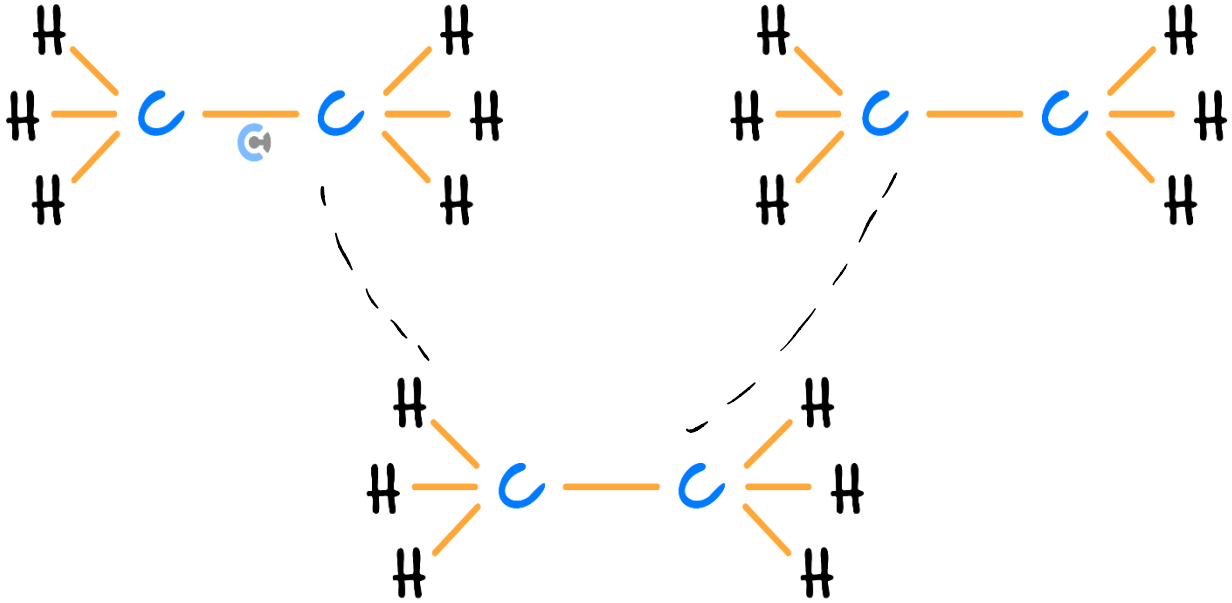
Exploration: Intermolecular Bonds vs Intramolecular Bonds

- Consider ammonia (NH_3):
  - How are the covalent bonds located? *(Label Below)*



  - The covalent bond is: [Intramolecular]/[Intermolecular]

- Consider **dispersion forces** for ethane (C_2H_6):
  - **Location of Dispersion Forces:** *(Label Below)* [Within ethane]/[Between molecules]
  - **Type of Bond:** *(Label Below)* [Intramolecular]/[Intermolecular]



Definition

Intermolecular vs Intramolecular Bonding

- Intermolecular bonds are bonds which occur **between** molecules.
- Intramolecular bonds are bonds which occur **within** molecules.

Space for Personal Notes

Try some questions!

Question 3

Classify each of the following as either an intermolecular bond or intramolecular bond:

a. Dipole-dipole attraction:

[Intermolecular]/[Intramolecular] bond

b. Metallic bonds:

[Intermolecular]/[Intramolecular] bond

c. Ionic bonds:

[Intermolecular]/[Intramolecular] bond

d. Hydrogen-bonds:

[Intermolecular]/[Intramolecular] bond

e. Ion-dipole bonds:

[Intermolecular]/[Intramolecular] bond

Question 4 Additional Question.

State what happens to the bonding in water when it boils. Reference both intermolecular and intramolecular bonds.

Intermolecular bonds (dispersion and H-bonds) will break, but intramolecular (covalent) stays intact.

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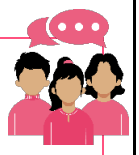
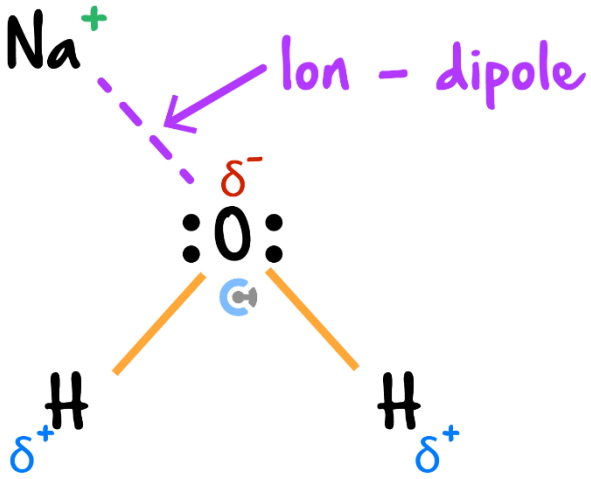
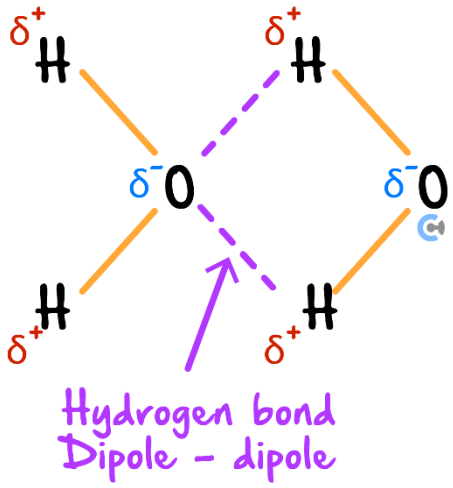
Let's compare the strength of all the intermolecular bonds we've learnt about!



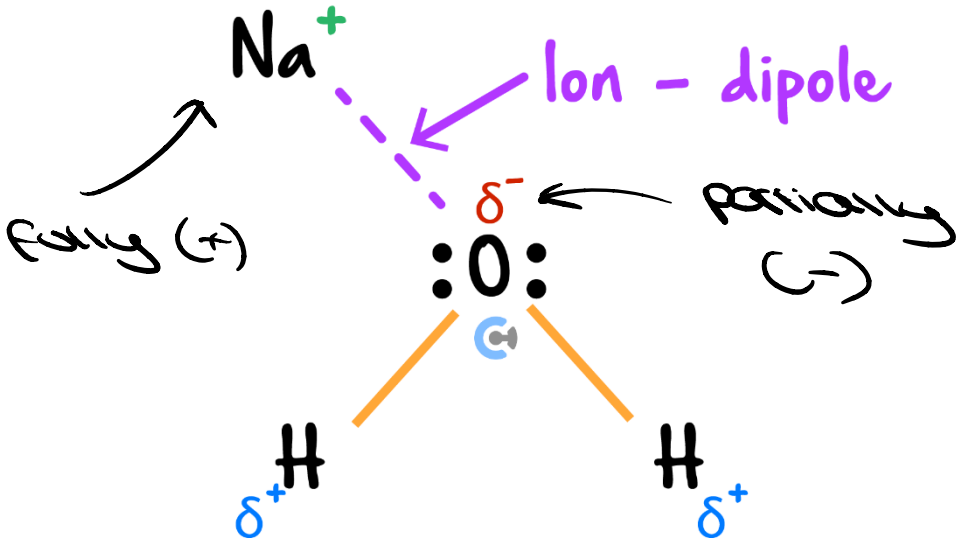
Discussion: Which is stronger - ion-dipole bonds or dipole-dipole/hydrogen bonds?



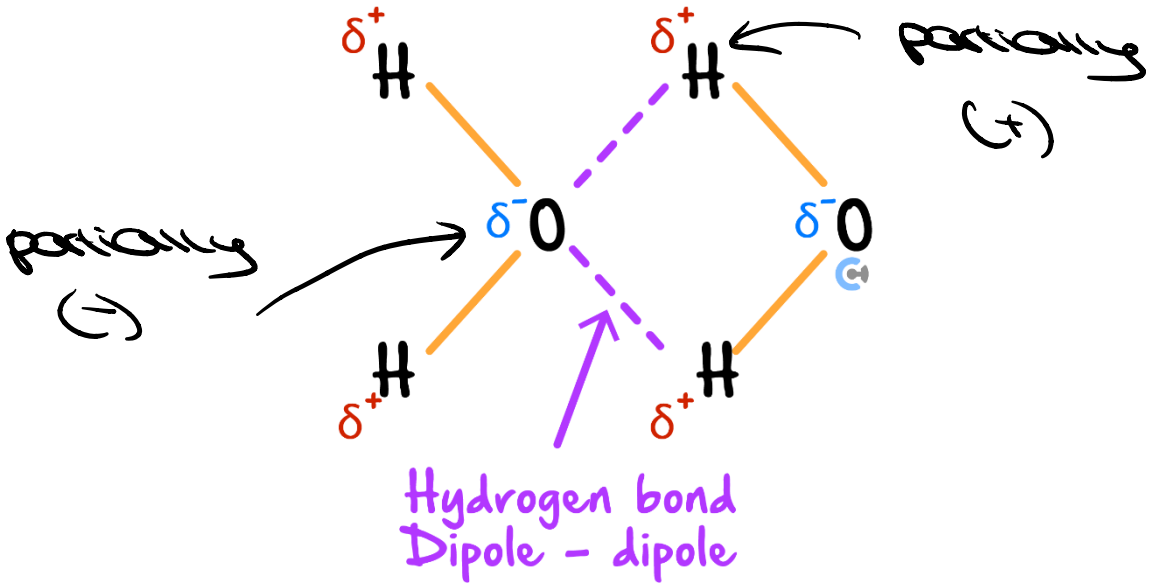


Exploration: Ion-dipole vs Dipole-dipole/Hydrogen Bonds

- Consider an ion-dipole bond:
  - What type of charge does an ion have? [Full]/[Partial]
  - What type of charge is present in a dipole? [Full]/[Partial]
  - As such, what type of charges are involved in an **ion-dipole** bond? *(Label Below)*



- Consider a dipole-dipole/hydrogen bond:
  - What type of charge is present in a dipole? [Full]/[Partial]
  - What type of charge is present in another dipole? [Full]/[Partial]
  - As such, what type of charges are involved in a **dipole-dipole** bond? *(Label Below)*



- Which combination will have **stronger electrostatic attraction**? [Full & Partial]/[Partial & Partial]
- Which bond is **stronger**? [Ion-dipole]/[Dipole-dipole]

Definition

- **Observation #1:** Dipole-dipole/hydrogen bonds occur between partial charges only.
- **Observation #2:** Ion-dipole bonds occur between a partial charge and a full charge, and thus have stronger electrostatic attraction.
- **Result:** As such, ion-dipole bonds are stronger.

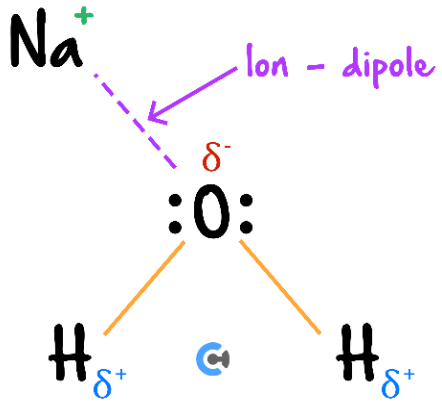
Space for Personal Notes

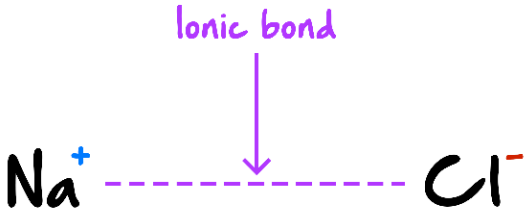
Strength of Intermolecular Bonds

Dispersion	Dipole-Dipole	Hydrogen	Ion-dipole
Occurs between all molecules.	Occurs between polar molecules.	Occurs between FON and hydrogen covalently bonded to FON.	Occurs between partially charged dipoles and fully charged ions.
Strength of Bonding →			

What about the intramolecular bonds?

Discussion: Which is stronger - ionic bonds or ion-dipole bonds?





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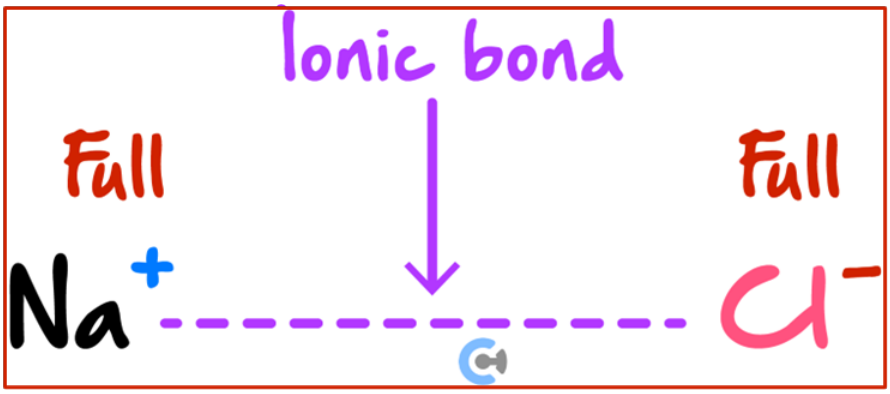
Exploration: Ionic vs Ion-Dipole Bonding

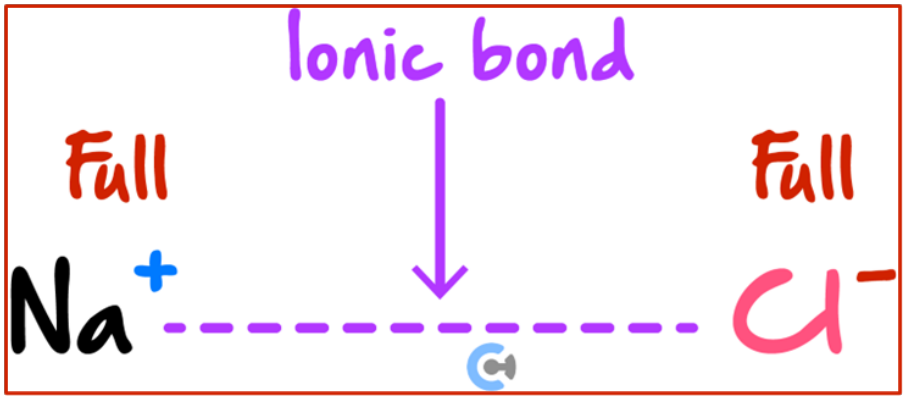
- **Ion-dipole** bonds contain:
  - A [partially]/fully] charged dipole.
  - A [partially]/[fully] charged ion.
- Consider an **ionic** bond:
  - What type of charge do cations have? [Full]/[Partial]
  - What type of charge do anions have? [Full]/[Partial]
  - What type of charges are involved in an **ionic** bond? *(Label Below)*



  - Stronger type of bonding: [Ionic]/[Ion-dipole]

Ionic vs Ion-Dipole Bonding

- **Definition:** As ionic bonds occur between full charges whereas ion-dipole bonds occur between partial charges, **ionic** bonds are stronger.



NOTE: You do NOT need to be able to compare **intramolecular** bonds' strength with one another as it is very complicated!

ALSO NOTE: Some teachers say that covalent bonds are the strongest bond of all but this is **not** necessarily correct!

Try some questions!

Question 5

State which of the following is correct regarding chemical bonds.

A. Intermolecular bonds are generally stronger than intramolecular bonds.

B. Ion-dipole bonding is the strongest type of intramolecular bond.

C. Ionic bonding is generally stronger than dipole-dipole bonding.

D. Bond strength is random and cannot be compared.

Question 6 Additional Question.

In what real-world context do ion-dipole bonds usually form?

Dissolution

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Sub-Section: Dissolution

Context

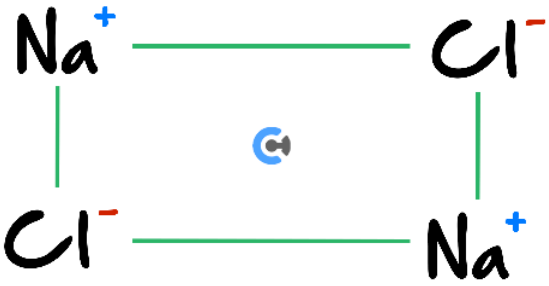
- We have learnt how all the **intra**molecular and **inter**molecular bonds work.
- We have compared their **strengths** to one another.
- But how do these ideas relate to **dissolving** chemicals?

Dissolution

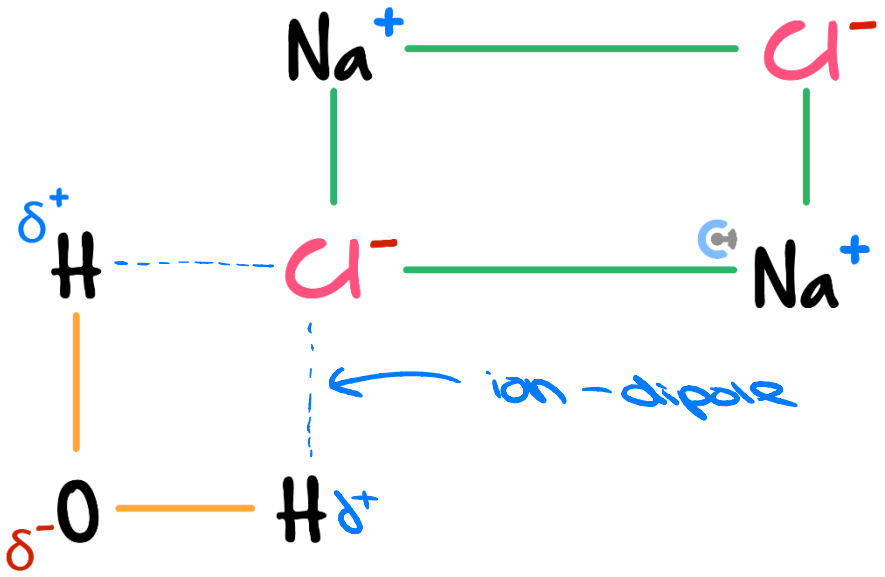
- dissolution is another term used to describe the process whereby a chemical dissolves.

Exploration: Sodium chloride ($NaCl$) dissolving

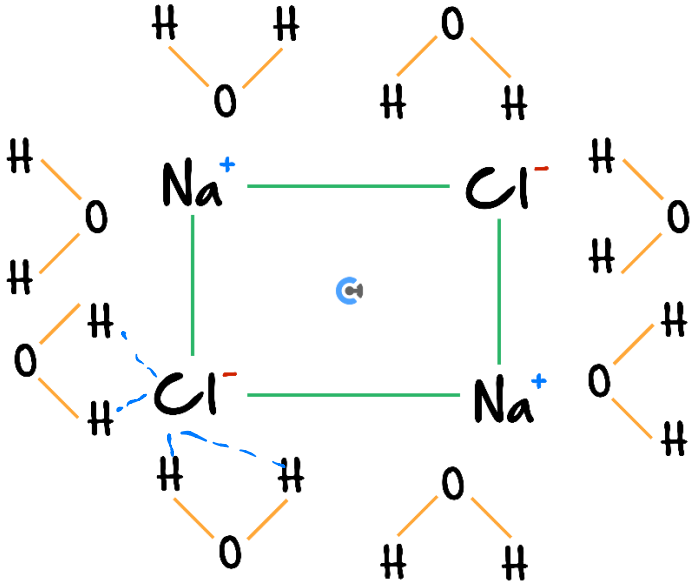
- Consider a scoop of table salt ($NaCl$) dropped into water:



- What type of bond will exist between a **single** water molecule and a chloride ion (Cl^-) in the ionic lattice structure? *(Label Below)*



- **Strength of Single Ion-Dipole Bond within $NaCl$:** [Weaker]/[Stronger]
- **Effect of Single Water Molecule on $NaCl$:** [Nothing]/[Breaks lattice]
- **Effect of Multiple Water Molecules on $NaCl$:** *(Label Below)*



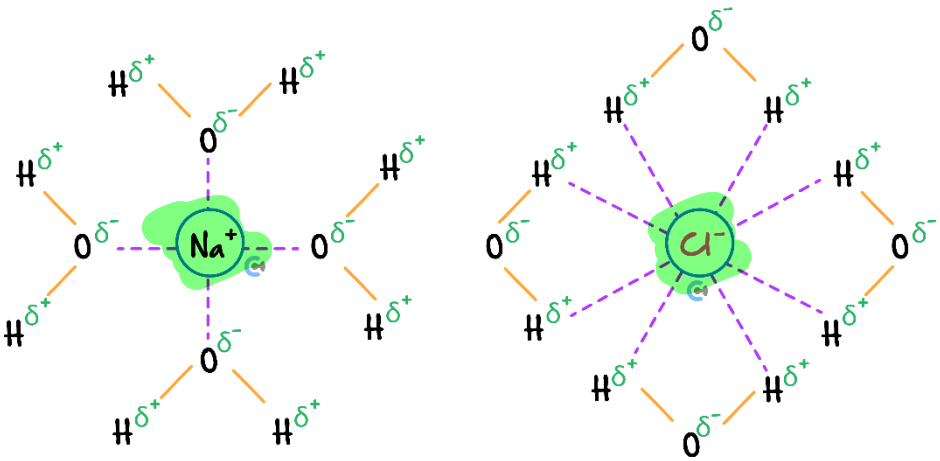
- **Stronger Bonding Type:**

[Ionic bonding between the Na^+ & Cl^- ions]/[Multiple ion-dipole bonds of the Na^+ & Cl^- with water]

What does this look like?

Exploration: Solubility Visualised

- Watch this video of water pulling apart sodium chloride at $2x$ speed:
- https://www.youtube.com/watch?v=xdedxfhcpWo
- When completely submerged in water, sodium cations (Na^+) and chloride ions (Cl^-) will undergo the following ion-dipole bonds with water:



- The reaction that the sodium chloride ($NaCl$) undergoes is as follows:

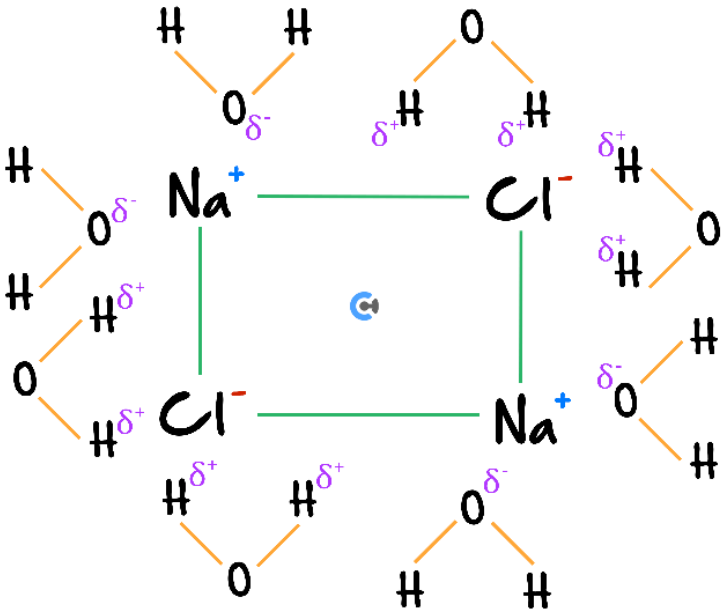
$NaCl(s) \xrightarrow{H_2O(l)} Na^+(aq) + Cl^-(aq)$

- Hence, sodium chloride ($NaCl$) is the solute which is dissolved in the water solvent.

Space for Personal Notes

Dissolution in Water

- **Power in Numbers:**
  - One single ion-dipole bond is **not stronger** than the ionic bond in the ionic lattice structure.
  - But **multiple** ion-dipole bonds can overpower the ionic bonds within the ionic lattice structure.



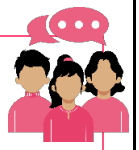
- The water molecules will slowly pull apart the sodium ions (Na^+) and chloride ions (Cl^-) from one another, effectively dissociating the ionic lattice structure.

Solute

- **Definition:**
  - A solid substance which is dissolved in the solvent.

Solvent

- **Definition:**
  - A liquid substance in which a solute is dissolved in.



Discussion: What state are the Na^+ and Cl^- ions in once they've been dissolved in water?

Aqueous

Aqueous

- **Definition:**
  - A 'state' of matter where a solute is dissolved in a **water** solvent.
- **Denoted By:**
  - (aq)
- **Equation:**
  - $NaCl(s) \xrightarrow{H_2O(l)} Na^+(aq) + Cl^-(aq)$

Solubility

- Solubility is the ability of a [solute]/[solvent] to dissolve in a [solute]/[solvent].

How do covalent molecules dissolve?

Active Recall: Why do some molecules share electrons rather than transferring them, when both methods can give the atoms full outer shells?

electronegativity difference

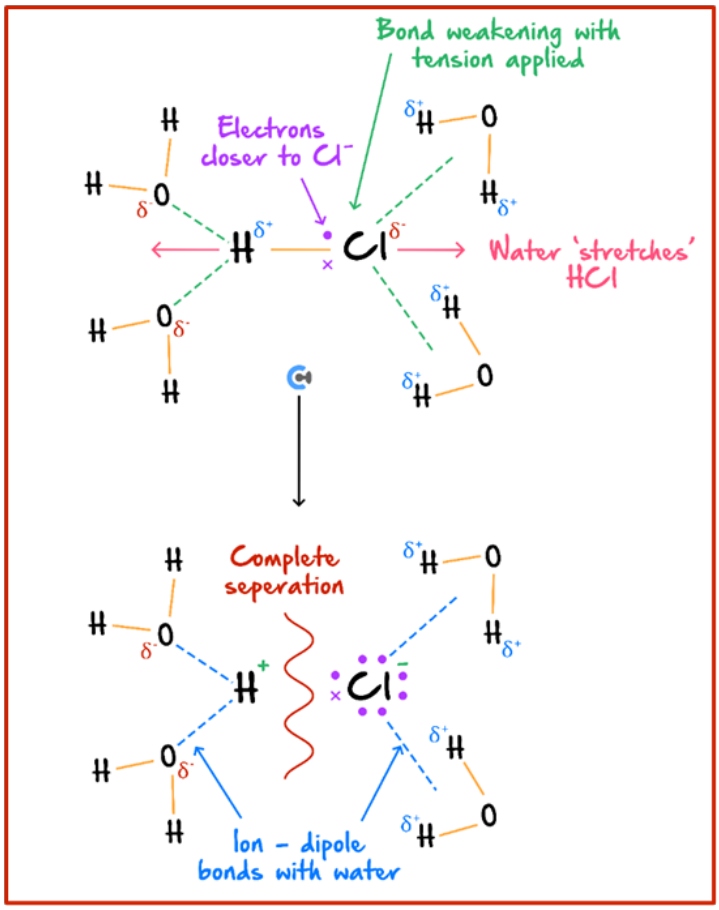
$0.4 < x < 1.8$

Space for Personal Notes

Exploration: Ionisation of Compounds in Water

- What bond exists within an HCl molecule? *(Label Below)*

- The electronegativity difference between hydrogen and chlorine is 1.4.
- Below the 1.8 requirement for an ionic bond, so it is only polar.
- When HCl is dissolved in water:
  - What do the surrounding water molecules do to HCl? *(Label Below)*
  - What does this tension do to the pre-existing covalent bond? *(Label Below)*
  - What happens to the H and the Cl? *(Label Below)*
  - What charges do the H and Cl now each have? *(Label Below)*
  - What bonds are formed between the water molecules and the ions? *(Label Below)*

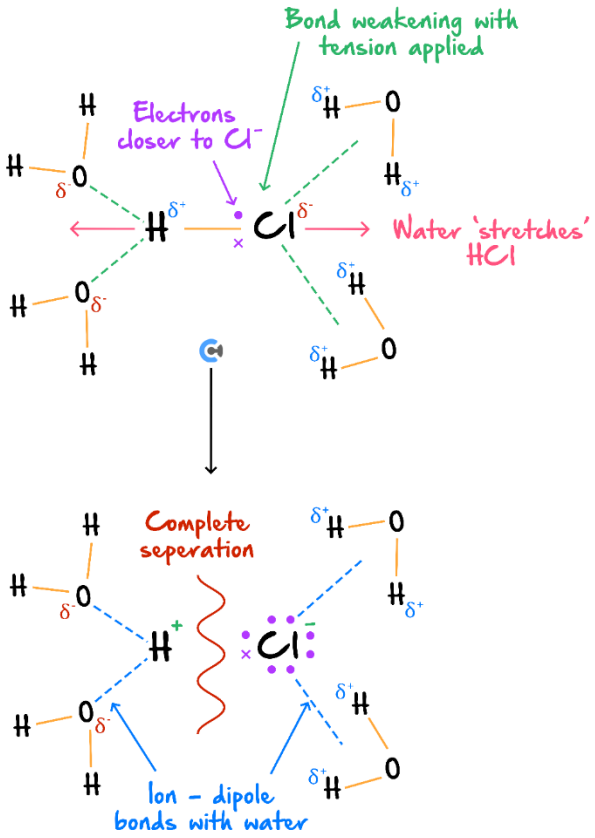


- The equation depicting the process can be written as such: *(Label Below)*
- What type of bonding exists before and after dissolution? *(Label Below)*

$$HCl(g) \xrightarrow[]{\text{Water}} H^+(aq) + Cl^-(aq)$$

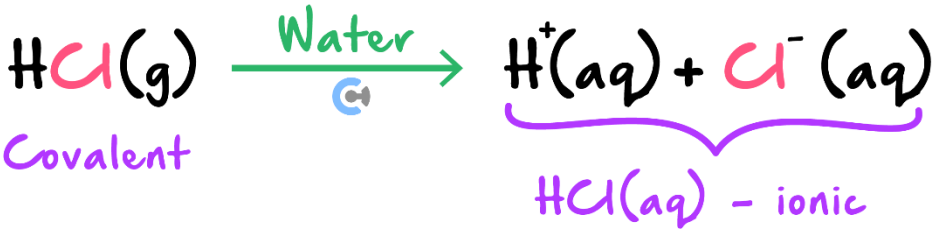
Definition

HCl Dissolution



- This process is known as [redacted], as we have turned the HCl into ions.

- The process is **also** called dissociation as the HCl has been broken apart.



NOTE: $HCl(g)$ is a covalent molecule but $HCl(aq)$ is an ionic compound.

ALSO NOTE: A similar process occurs with molecules such as hydrogen bromide $(HBr(g)$ turning into $HBr(aq))$.

Recall!

Active Recall: What is solubility?

Solubility is the ability for a solute to dissolve in a solvent.

Let's have a look at a question together!

Question 7 Walkthrough.

Write the equation for the dissolution of a sample of solid magnesium nitrate in water.

Mg^{2+} NO_3^-

$Mg(NO_3)_2(s) \xrightarrow{H_2O(l)} Mg^{2+}(aq) + 2NO_3^-(aq)$

TIP: Use the databook to figure out the ionic compound's formula first!

Your Turn!

Question 8

Write the equation for the dissolution of each of the following compounds;

a. Sodium sulphate in water.

$Na_2SO_4(aq) \xrightarrow{H_2O(l)} 2Na^+(aq) + SO_4^{2-}(aq)$

b. Ammonium chloride.

$NH_4Cl(s) \xrightarrow{H_2O(l)} NH_4^+(aq) + Cl^-(aq)$

Question 9 (2 marks)

Explain the process by which HBr(g) dissolves in water.

- HBr → covalent molecule
- In water, the δ^- on O attracts the H^+
  the δ^+ on H attracts the Br^-
- This splits the covalent bond
  to form H^+ & Br^-

Question 10 Additional Question.

Write the balanced chemical equation for the dissolution of calcium phosphate.

$$Ca_3(PO_4)_2(s) \rightarrow 3Ca^{2+}(aq) + 2PO_4^{3-}(aq)$$

Space for Personal Notes

Section B: Precipitation

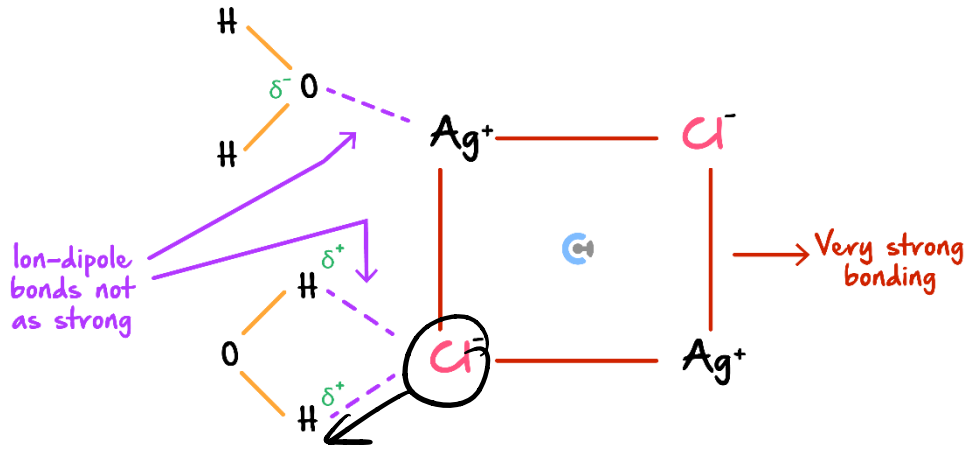
Sub-Section: Solubility

Discussion: Why are some chemicals insoluble?

Cover Below

Exploration: Insoluble Compounds

- Consider AgCl in water:
  - What type of bonds are present? *(Label Below)*
  - How does the strength of each of these bonds compare? *(Label Below)*



- In this scenario, it happens to be that:

Ionic Bonds > Ion-Dipole Bonds

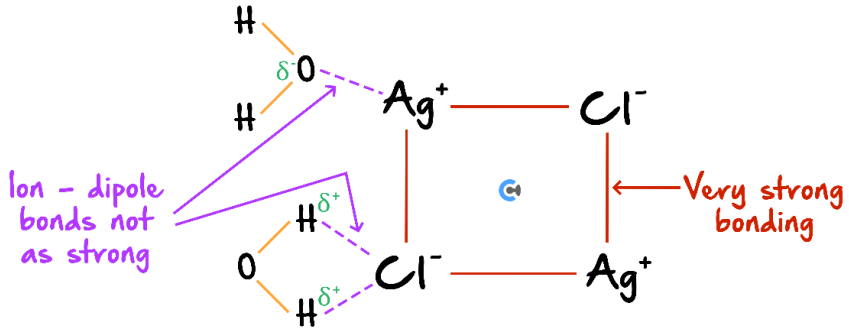
- AgCl will: [Dissociate]/[Stay Together]

NOTE: The reason why some compounds' ionic bonds are stronger than the ion-dipole bonds formed with water is **NOT** in the Study Design!

Insolubility

- For insoluble compounds, the ion-dipole bonds formed with water and the ionic lattice structure are ~~not strong~~ strong enough to dissociate the ionic compound.

Ionic Bonds > Ion – Dipole Bonds



So then how do we know what is soluble and what is insoluble?

Databook: Solubility Tables

- ~~Solubility~~ Solubility table will generally be provided to deduce what is soluble and what is insoluble.

9. Solubility table

Salts	Soluble	Insoluble
sodium	All	None
potassium		
ammonium		
nitrate		
ethanoate		
bromide, chloride, iodide	Most are soluble.	lead(II), silver, $CuBr_2$, CuI_2
sulfate	Most are soluble.	barium, calcium, lead(II), silver
carbonate	Group 1 ions, ammonium	Most are insoluble.
phosphate	Group 1 ions, ammonium	Most are insoluble.
hydroxide	Group 1 ions, ammonium	Most are insoluble.

What if we don't have a solubility table?

TIPS: A good acronym to remember which compounds are generally soluble is the acronym _____ :

- S – sodium (Na^+)
- N – nitrate (NO_3^-)
- A – ammonium (NH_4^+)
- P – Potassium (K^+)
- E – Ethanoate (CH_3COO^-)

SNAPE

NOTE: Compounds which do not have at least one SNAPE are generally insoluble.

ALSO NOTE: The reason why SNAPE works is if we look at the solubility tables, the compounds with _____ are SNAPE.

no exceptions

Let's look at a question together!

Question 11 Walkthrough.

a. State whether each of the following is soluble or insoluble in water, **without** looking at a solubility table:

i. KNO_3.

Yes

Soluble

ii. Na_2SO_4.

Yes

Soluble

iii. $BaCO_3$.

Insoluble

b. Verify each of your answers above by using a solubility table.

KNO_3 and Na_2SO_4 are soluble. $BaCO_3$ is insoluble.

NOTE: Whilst SNAPE works, it is not 100% accurate, which is why solubility tables exist.

ALSO NOTE: The reason we are covering SNAPE is because many schools do not allow you to use a solubility table/databook during your tests and exams!

Recall!

Active Recall: What does SNAPE stand for?

- S –
- N –
- A –
- P –
- E –

Your Turn!

Question 12

a. **Without** referring to solubility tables, identify which of the following substances are soluble and which are insoluble:

K_3PO_4, $PbSO_4$, $(CH_3COO)_2Ca$, $(NH_4)_2SO_4$, $AgBr$, $LiOH$, $Ba_3(PO_4)_2$

Soluble	Insoluble
K_3PO_4, $Ca(CH_3COO)_2$, $(NH_4)_2SO_4$	$PbSO_4$, $AgBr$, $LiOH$, $Ba_3(PO_4)_2$

b. Verify each of your answers above using a solubility table.

K_3PO_4, $Ca(CH_3COO)_2$, $(NH_4)_2SO_4$ are soluble and $PbSO_4$, $AgBr$, $LiOH$, $Ba_3(PO_4)_2$ are insoluble

Question 13 Additional Question.

State one example of a compound which is soluble but is not found in SNAPE.

$MgCl_2$ is one example.

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Sub-Section: Introduction to Precipitation

Let's take a look at what happens to these insoluble compounds when they interact with water!

Active Recall: What is the solubility of $AgCl$ in water?

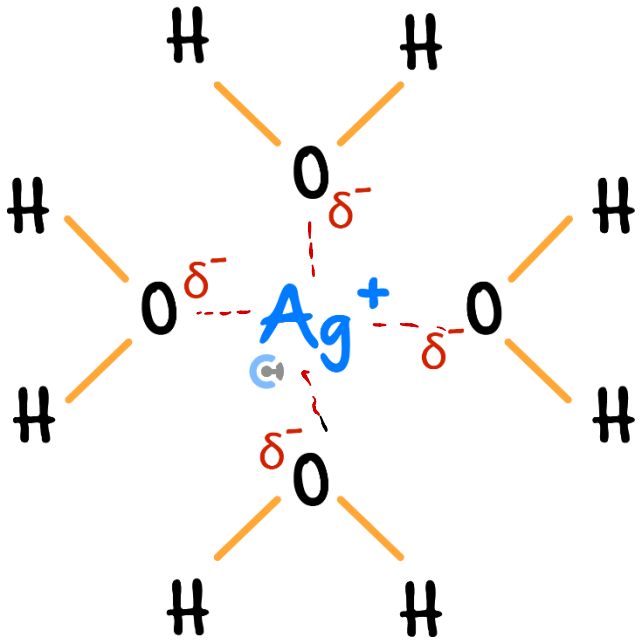
Insoluble

Exploration: Insoluble Compounds

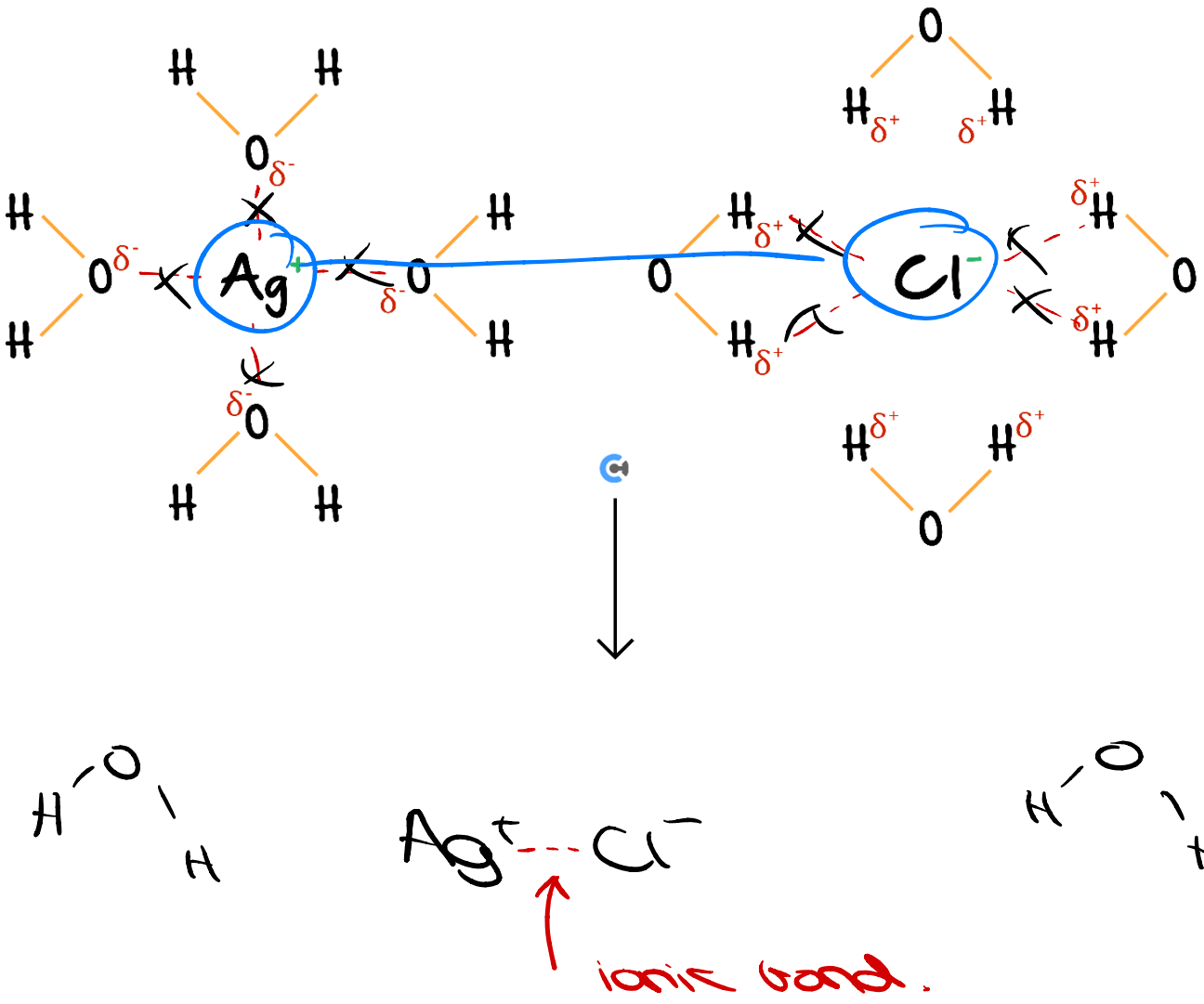
- Are silver cations (Ag^+) by themselves soluble? How about chloride ions (Cl^-) by themselves?

Yes

- When the ions exist by themselves, they can form ~~ion-dipole~~ bonds with water. *(Label Below)*



- Consider mixing together a solution only containing dissolved $Ag^+(aq)$ and another with only dissolved $Cl^-(aq)$:
  - How strong is the attraction between Ag^+ and Cl^-? *(Label Below)*
  - As a result, what will this look like after some time? *(Label Below)*
  - What will the state of $AgCl$ be? *(Label Below)*



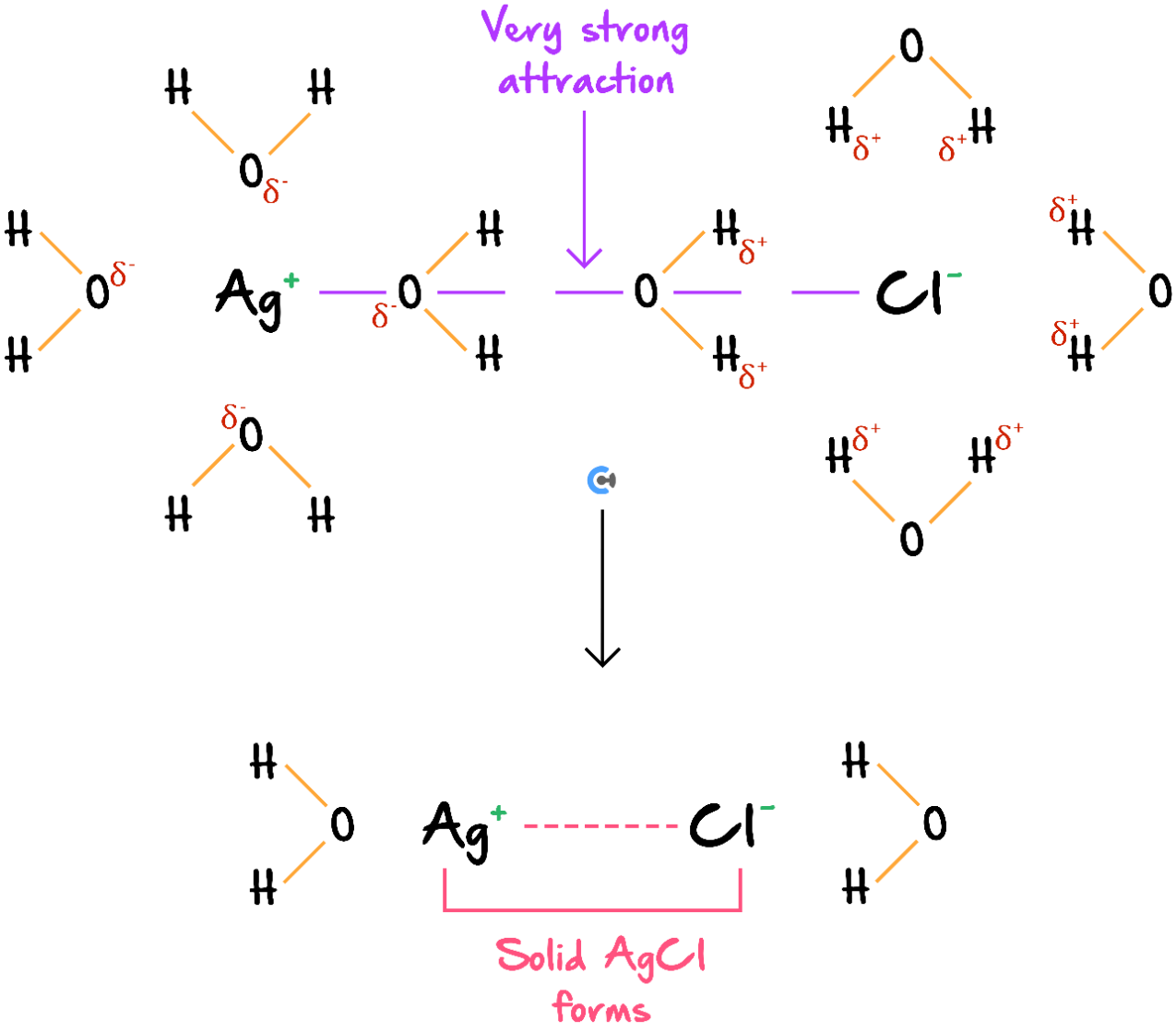
- The reaction can be written as follows:

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

- The insoluble compound is a precipitate, and the process where the precipitate is formed a precipitation reaction.

Precipitation

- **Definition:**
  - The process where a solid is formed from a solution.
  - The solid forms due to it being insoluble in water.

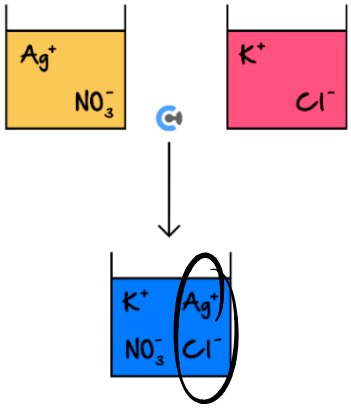


Discussion: Are ions found on their own? Can we have a solution containing just $Ag^+(aq)$ and another containing just $Cl^-(aq)$, for example?

[Yes] / ~~[No]~~

Exploration: Precipitation Reactions

- The following is a video showing the precipitation reaction forming silver chloride precipitate ($AgCl$):
  - https://www.youtube.com/watch?v=xR_VZX0z64A
- Ag^+ ions and Cl^- are generally **not** found alone and are usually part of another **ionic** compound.
- If we consider silver nitrate ($AgNO_3$):
  - Is silver nitrate soluble? Yes
- If we consider potassium chloride (KCl):
  - Is potassium chloride soluble? Yes
- What happens if we mix silver nitrate ($AgNO_3$) and potassium chloride (KCl) together? *(Label Below)*



- If these two solutions are mixed together, the following equation will form:

$$AgNO_3(aq) + KCl(aq) \rightarrow KNO_3(aq) + AgCl(s)$$

- Reactants could've been written as either:

$$AgNO_3(aq) + KCl(aq)$$

or

$$Ag^+(aq) + NO_3^-(aq) + K^+(aq) + Cl^-(aq)$$

  - Aqueous ions can be split up as they are merely **floating** around in solution, and **not** strictly bound together.

- The equation could be written as such:

$$AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$$

or

$$Ag^+(aq) + NO_3^-(aq) + K^+(aq) + Cl^-(aq) \rightarrow AgCl(s) + K^+(aq) + NO_3^-(aq)$$

- Is there anything which can be 'cancelled out' on either side of the equation? *(Label Above)*
- As these ions are not participating in the overall reaction, we call them spectator ion.
- The equation can be simplified as such:

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

NOTE: An easy way to identify spectator ions is by searching for species which are aqueous before and after the reaction.

Precipitation Reactions

- As ions are not found alone, solutions **of ionic compounds** are generally mixed together.
- If one of the products is insoluble, a precipitate is formed.
- Aqueous ions can be split up as they are merely floating around in solution, and not strictly bound together.

$$AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$$

NOTE: As the $AgCl(s)$ forms an ionic lattice structure and is not dissolved in the solution, it cannot be written as $Ag^+(s) + Cl^-(s)$ as it is one compound.

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Net Ionic Equation

- If we now consider the two 'forms' of the same reaction we've seen:

$$AgNO_3(aq) + KCl(aq) \rightarrow AgCl(s) + KNO_3(aq)$$

or

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

- The top equation is called the full equation and the bottom equation is called the ionic equation.
- A (net) ionic equation omits spectator ions so as to only show the species which are reacting.
- Spectator ions are ions which are present before and after the reaction but do not participate in any reaction themselves.
- The full equation details all ions which is present before and after the reaction is completed.

Let's look at some questions together!

Question 14 Walkthrough.

Write the ionic equation from the full equation provided by identifying any spectator ions:

$$2NaBr(aq) + PbCl_2(aq) \rightarrow PbBr_2(s) + 2NaCl(aq)$$

a. Spectator ions

$Na^+(aq)$ / $Cl^-(aq)$

b. Ionic equation

$2Br^-(aq) + Pb^{2+}(aq) \rightarrow PbBr_2(s)$

REMINDER: Don't forget spectator ions are the ions which remain aqueous before and after the reaction.

Your turn!

Question 15

Write the ionic equation from the full equation provided and identify any spectator ions:

a. $HCl(aq) + KOH(aq) \rightarrow KCl(aq) + H_2O(l)$

i. Spectator ions

$Cl^-(aq)$ & $K^+(aq)$

ii. Net ionic equation

$H^+(aq) + OH^-(aq) \rightarrow H_2O(l)$

b. $HCl(aq) + MgO(s) \rightarrow MgCl_2(aq) + H_2O(l)$

i. Spectator ions

$Cl^-(aq)$

ii. Net ionic equation

$2H^+(aq) + MgO(s) \rightarrow Mg^{2+}(aq) + H_2O(l)$

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Question 16 Additional Question.

Write the ionic equation from the full equation provided and identify any spectator ions:

$$KNO_3(aq) + NaCl(aq) \rightarrow KCl(aq) + NaNO_3(aq)$$

a. Spectator ions

all

b. Net ionic equation

nothing all are spectators theres no real reaction occurring

NOTE: In equations such as the following:

$$KNO_3(aq) + NaCl(aq) \rightarrow KCl(aq) + NaNO_3(aq)$$

- There's no real reaction occurring – there are two solutions mixing together, and they still all remain dissolved in the solution.

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Sub-Section: Writing Full Precipitation Reactions

What if the full equation has not already been given?

Question 17 Walkthrough.

For each of the following:

i. Write the overall equation.

ii. List any precipitate formed.

iii. List any spectator ions.

iv. Write the corresponding net ionic equation.

$Pb(NO_3)_2$

$NaBr$

a. A solution of lead (II) nitrate and sodium bromide are mixed together.

Overall equation: $Pb(NO_3)_2(aq) + 2NaBr(aq) \rightarrow 2NaNO_3(aq) + PbBr_2(s)$

Precipitate formed: $PbBr_2(s)$

Spectator ions: Na^+ / NO_3^-

Net ionic equation: $Pb^{2+}(aq) + 2Br^-(aq) \rightarrow PbBr_2(s)$

b. A solution of ammonium chloride and potassium ~~ethanol~~ ethanoate are mixed together.

Overall equation: $NH_4Cl(aq) + KCH_3COO(aq) \rightarrow KCl(aq) + NH_4CH_3COO(aq)$

Precipitate formed: N/A

Spectator ions: All

Net ionic equation: N/A

NOTE: Precipitation reactions are also known as double displacement reactions as in each ionic compound, one of the ions is being 'displaced' with another ion.

Your turn!

Question 18

Write the:

a. Full equation for when aluminium nitrate ($Al(NO_3)_3$) is mixed with sodium sulphide (Na_2S).

$2Al(NO_3)_3(aq) + 3Na_2S(aq) \rightarrow Al_2S_3(s) + 6NaNO_3(aq)$

b. The corresponding net ionic equation.

$2Al^{3+}(aq) + 3S^{2-}(aq) \rightarrow Al_2S_3(s)$

Question 19

For each of the following, determine whether a precipitation reaction will form, and if so, write the **ionic** equation for the precipitation reaction.

a. KOH mixed with $AlCl_3$.

$Al^{3+}(aq) + 3OH^-(aq) \rightarrow Al(OH)_3(s)$

b. $Pb(CH_3COO)_2$ added to $NaNO_3$.

N/A

c. $NH_4OH + Na_2SO_4$.

N/A

Question 20 Additional Question.

State the identity of the precipitate when each of the following solutions is mixed together.

a. $K_3PO_4 + MgSO_4$.

Mg_3 (PO_4)_2 (s)

b. $Ba(NO_3)_2 + (NH_4)_2SO_4$.

BaSO_4 (s)

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Contour Checklist

☐ **Learning Objective: [1.9.1] Explain the process by which ionic compounds dissolve in water with reference to ion-dipole bonding**

Study Design

The use of solubility tables to predict and identify precipitation reactions between ions in solution, represented by balanced full and ionic equations including the state symbols: $(s), (l), (aq)$ and (g)

Key Takeaways

dispersion	dipole - dipole	hydrogen	ion-dipole
Occurs between all molecules.	Occurs between polar molecules.	Occurs between FON and hydrogen covalently bonded to FON	Electrostatic attraction between a **fully** charged [ion] / [dipole] and a [fully] / [partially] charged **dipole**.

- ☐ Ionic bonds occur between [full] / [partial] charges whereas ion-dipole bonds include **partial** charges, so [ionic] / [ion-dipole] bonds are stronger.
- ☐ dissolution is used to describe the process by which ionic compound dissolves
- ☐ A solute is a **solid** substance which is dissolved in the solvent.
- ☐ A solvent is the **liquid** in which the solute is dissolved
- ☐ Solubility is the ability of a [solute] / [solvent] to dissolve in a [solute] / [solvent]
- ☐ For **insoluble** compounds, the ion-dipole bonds formed are [strong enough] / [not strong enough] to dissociate the ionic compound:

Ionic Bonds > Ion-Dipole Bonds

Learning Objective: [1.9.2] Write balanced equations for ionic compounds dissociating/ionising in water

Study Design

The use of solubility tables to predict and identify precipitation reactions between ions in solution, represented by balanced full and ionic equations including the state symbols: $(s), (l), (aq)$ *and* (g)

Key Takeaways

- While one single ion-dipole bond is **not stronger** than the ionic bond in the ionic lattice structure, multiple ion-dipole bonds can _____ the strong ionic bonds within the ionic lattice structure.
- When table salt dissolves: water molecules slowly **pull apart** the Na^+ *and* Cl^- ions from one another, effectively _____ the ionic lattice structure.
- When ionic compounds dissolve, it is also known as _____, as the compound is split into ions.
- The process is also called _____ as the compound has been broken apart.
- _____ is generally written above the arrow in a dissolution equation

Learning Objective: [1.9.3] Identify which compounds will or will not dissolve in water, with reference to SNAPE and/or solubility tables

Study Design

The use of solubility tables to predict and identify precipitation reactions between ions in solution, represented by balanced full and ionic equations including the state symbols: $(s), (l), (aq)$ and (g)

Key Takeaways

- A solubility table will generally be provided to deduce what is soluble and what is insoluble.
- To determine what is soluble in water, we can also use the acronym SNAPE *(Label Below):*
  - S - Na^+
  - N - NO_3^-
  - A - NH_4^+
  - P - K^+
  - E - CH_3COO^-

Learning Objective: [1.9.4] Write full & ionic equations for precipitation reactions

Study Design

The use of solubility tables to predict and identify precipitation reactions between ions in solution, represented by balanced full and ionic equations including the state symbols: $(s), (l), (aq)$ and (g)

Key Takeaways

- precipitation is the process where a **solid** is formed from a solution.
- The solid forms due to it being [soluble] / [insoluble] in water
- Aqueous ions can be split up as they are merely floating around in solution, and not strictly bound together
- A (net) ionic equation omits spectator ions so as to only show the species which are reacting
- Spectator ions are ions which are present before and after the reaction but are not involved in any reaction themselves.
- The full equation details everything which is present before and after the reaction is completed.

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