

# Annotated Lecture Slides for *Sugar and Salt Solutions*

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**COURSE:**

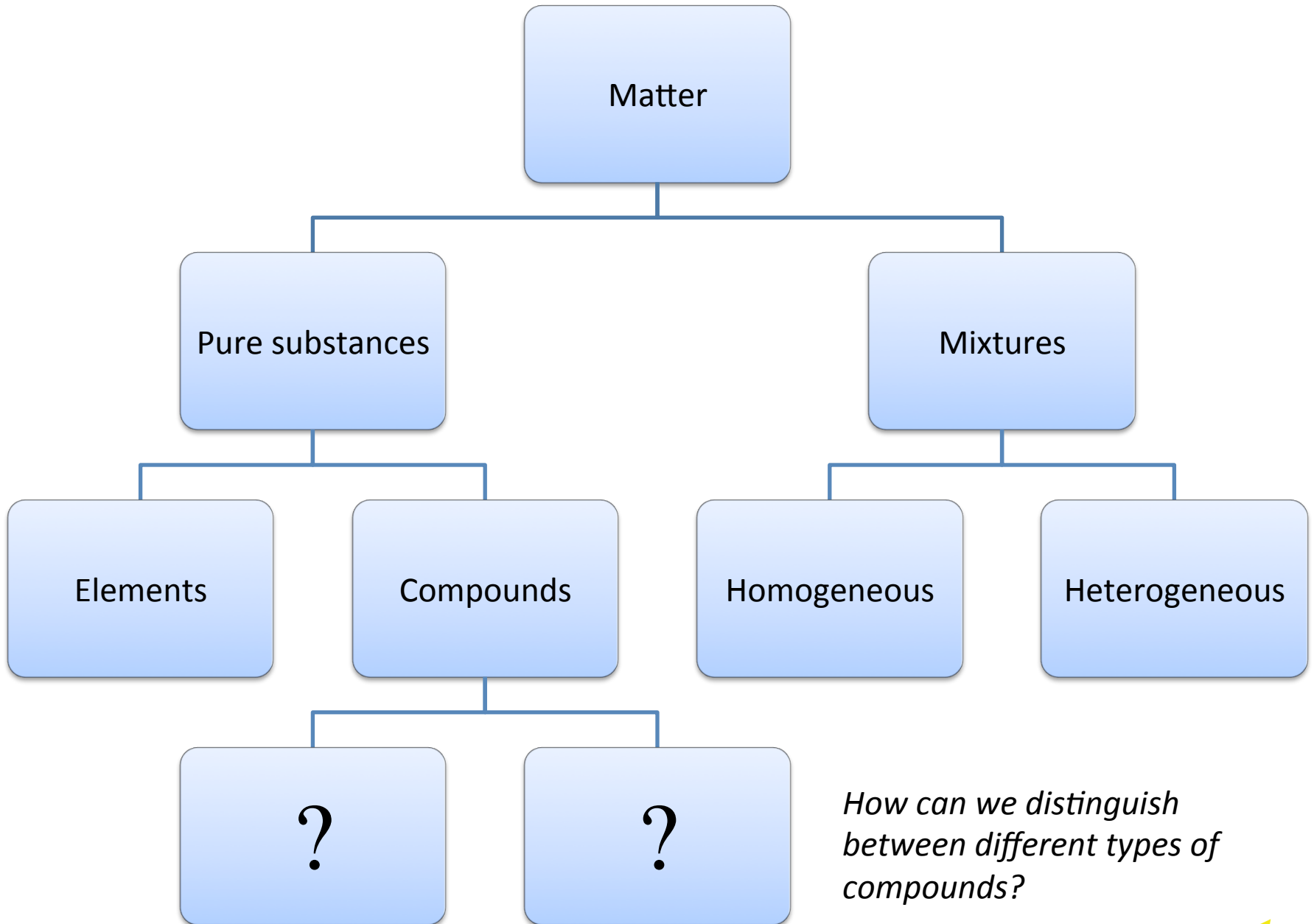
Introductory Chemistry

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# Learning Goals

- Explain the difference between the conductivity of solutions of ionic and molecular compounds based on the presence or absence of freely moving charged particles
- Describe the atomic-level structural features of ionic compounds
- Describe the forces involved in ionic bonding
- Identify if solutions contain ionic or molecular compounds based on conductivity
- Identify if solutions contain ionic or molecular compounds based on atomic-scale representations
- Describe the bonding in ionic compounds of polyatomic ions
- Determine if a chemical compound is best described as ionic or molecular based on its chemical composition, specifically whether it contains metal and non-metal elements or not



*How can we distinguish between different types of compounds?*

How does the **atomic-level structure** of compounds affect their **observable properties**?

**Conductivity  
in solution**



**Types of  
chemical bonds**

How can we use the **periodic table** to predict the bonding and properties of compounds?

Beaker Contents	Observations
Water	
Water + Salt	
Water + Sugar	

Beaker Contents	Observations
Water	No conductivity (lightbulb does not light)
Water + Salt	Lightbulb lights up. More salt added = brighter bulb. Solid salt by itself does not conduct.
Water + Sugar	No conductivity (lightbulb does not light)

*Why do these solutions have different conductivity?*

*What is different about dissolving salt vs. sugar in water?*

# Conductivity

For a substance or mixture to conduct electricity...

- It must contain charged particles
- Charged particles must be free to move or migrate

*But we know both salt and water have no overall charge, separately....*



# *When salt (NaCl) dissolves in water, ...*

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**it will produce...**

**Because...**

**A**       $[\text{NaCl}]^+$  molecules      It transfers electrons to the water.

**B**       $\text{Na}^+$  and  $\text{Cl}^-$  ions      Electrons are transferred from  
Na atoms to Cl atoms

**C**       $\text{Na}^+$  and  $\text{Cl}^-$  ions      The ions in the salt separate

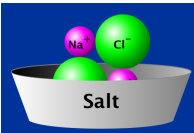
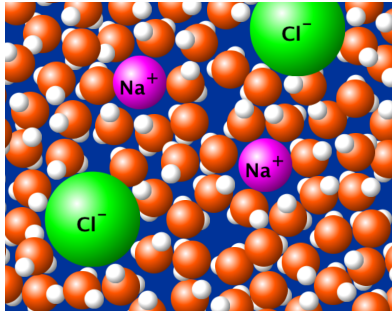
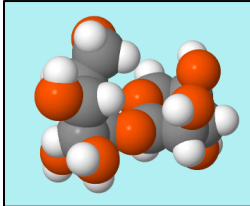
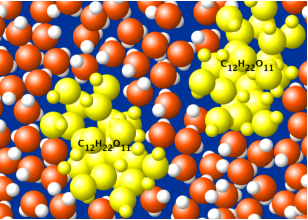
**D**       $\text{H}^+$  and  $\text{OH}^-$  ions      It forces water to break into  $\text{H}^+$  and  
 $\text{OH}^-$  ions

**E**      More than one of the above

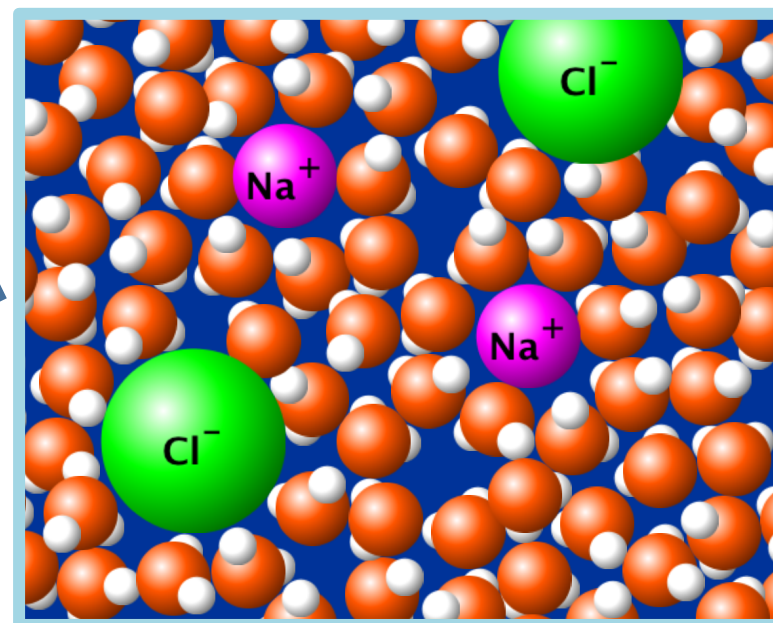
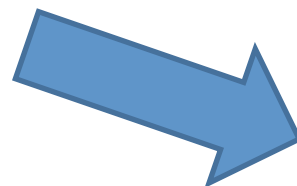
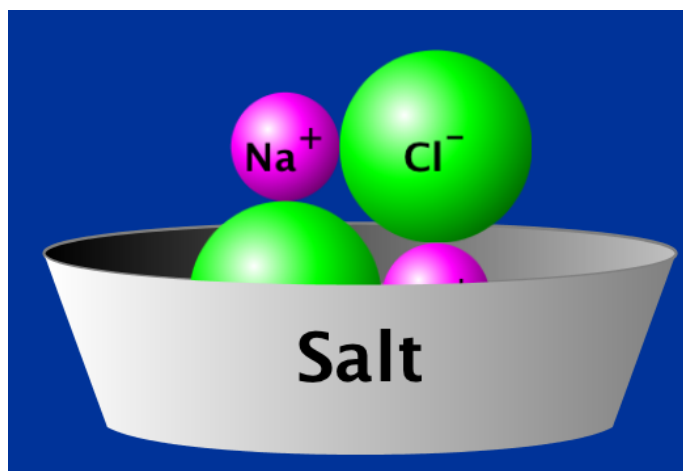
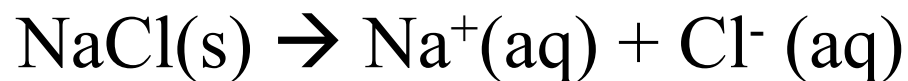
# What's happening at the atomic level?

Beaker Contents	Observations	
Water + Salt	Before	After
Water + Sugar	Before	After

# What's happening at the atomic level?

Beaker Contents	Observations	
Water + Salt	<p data-bbox="857 505 993 544"><b>Before</b></p>  <ul data-bbox="884 648 1174 805" style="list-style-type: none"><li>- Ions</li><li>- Multiple repeating units</li></ul>	<p data-bbox="1503 505 1605 544"><b>After</b></p> 
Water + Sugar	 <p data-bbox="919 939 1166 978">- No charges</p>	 <ul data-bbox="1282 1158 1765 1279" style="list-style-type: none"><li>- No charges</li><li>- Same structure (highlighted in yellow for visibility)</li></ul>

# Ionic Compound Example

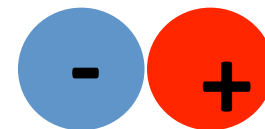


## Key features of ionic solid:

- Repeated units in larger lattice
- Units are made of charged ions

# Ionic Bonding

- A type of chemical bond due to the attractive electrostatic force between cations and anions.
- Electrostatic forces: attraction/repulsion that exists between charged particles.



Sodium chloride is solid at room temperature:  $\text{NaCl}_{(s)}$

Will *melted* sodium chloride  $\text{NaCl}_{(l)}$  conduct electricity?

A. Yes

B. No

C. It depends

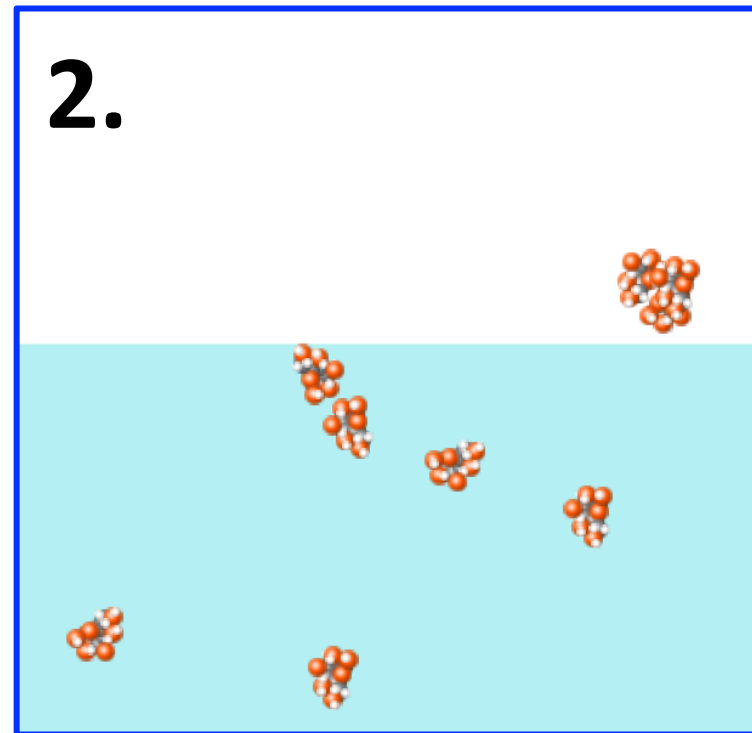
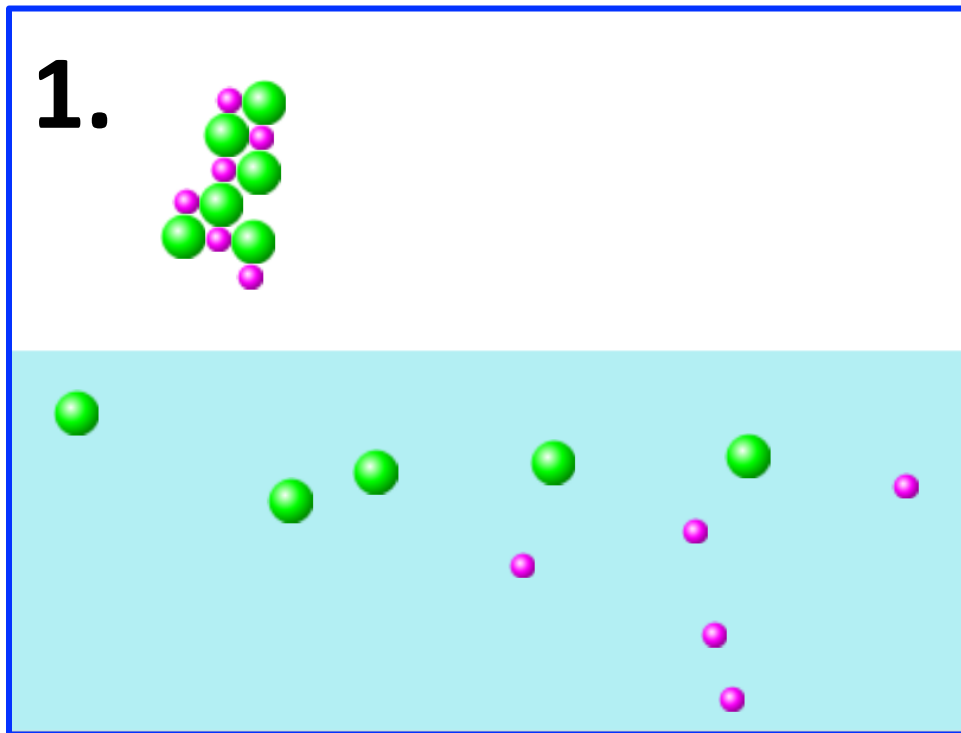
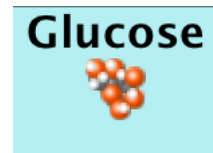
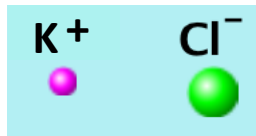
Electrolyte	Non-electrolyte

Electrolyte	Non-electrolyte
Conducts electricity	Does not conduct electricity
Release ions when dissolved in water  ( <b>Dissociation</b> OR <b>ionization</b> )	No mobile or dissociated ions

- ✓ ionic compounds are always electrolytes (*if* they dissolve in water).



*Which box shows an electrolyte dissolving in water?*



a. Box 1

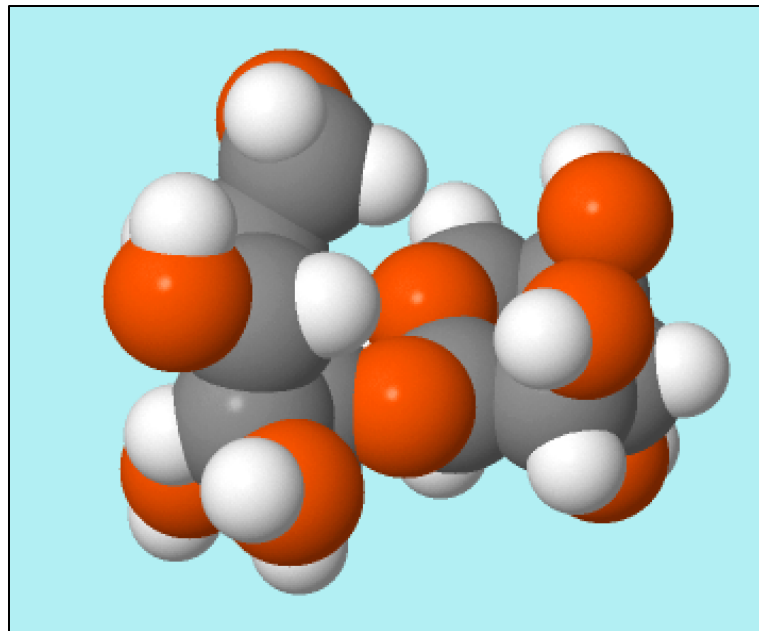
b. Box 2

c. Both

d. Neither

# Molecular Compound Example

- Discrete units
- Atoms held together by covalent bonds
- *Usually* do not dissociate in water



Sucrose,  $C_{12}H_{22}O_{11}$

# Covalent Bonding

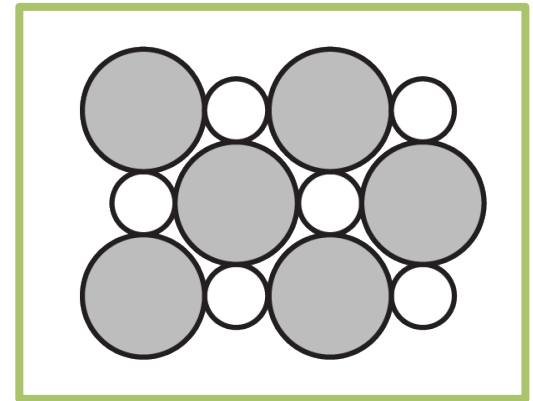
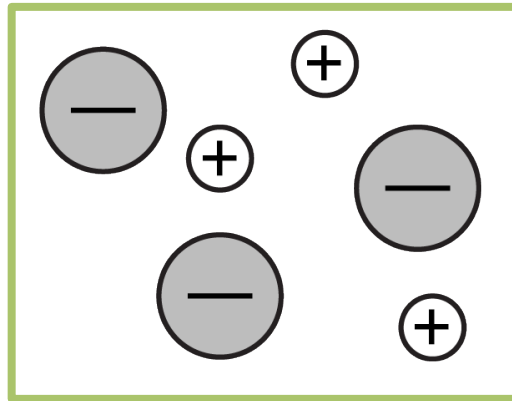
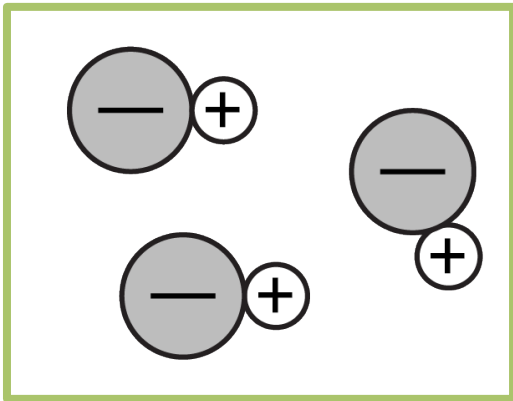
Chemical bonds due to the sharing of electrons by two (or more) atoms

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**Description:**

Graph depicting lower energy state of covalently bonded  $H_2$  molecule compared to H atoms separated by a large distance

How many of these pictures correctly depict the all of the features of solid NaCl?



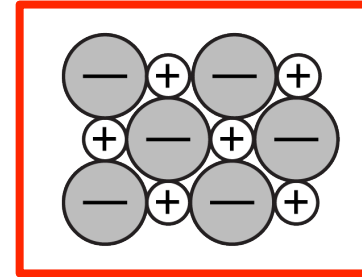
a. Zero

b. 1

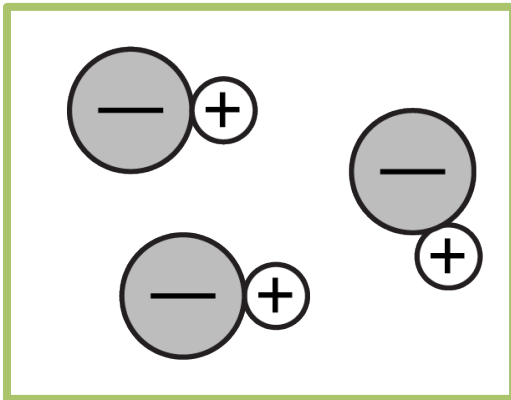
c. 2

d. 3

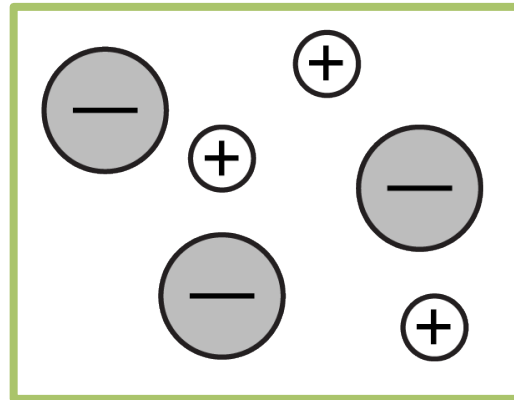
A correct (and complete) 2D representation of solid NaCl.



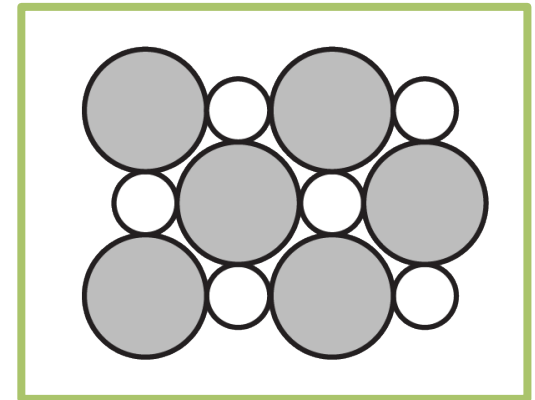
How many of these pictures correctly depict the all of the features of solid NaCl?



Incorrect – solid NaCl doesn't form discrete molecules.



Incorrect – solid NaCl does not dissociate (until we dissolve it in water)



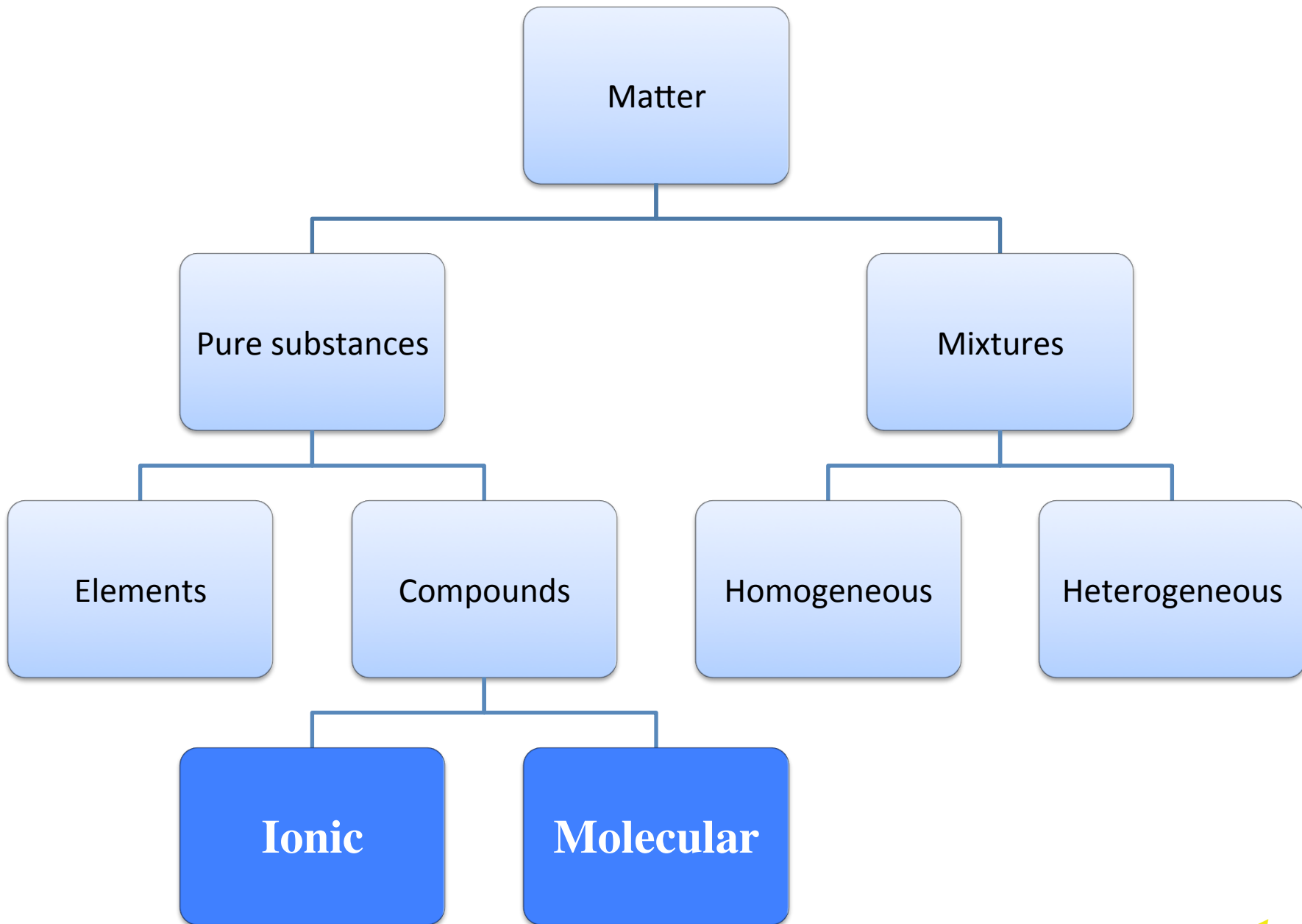
Incorrect, unless we define the circles as ions – solid NaCl does form an extended lattice like this, but it is made of charged ions even when it's a solid.

a. Zero

b. 1

c. 2

d. 3

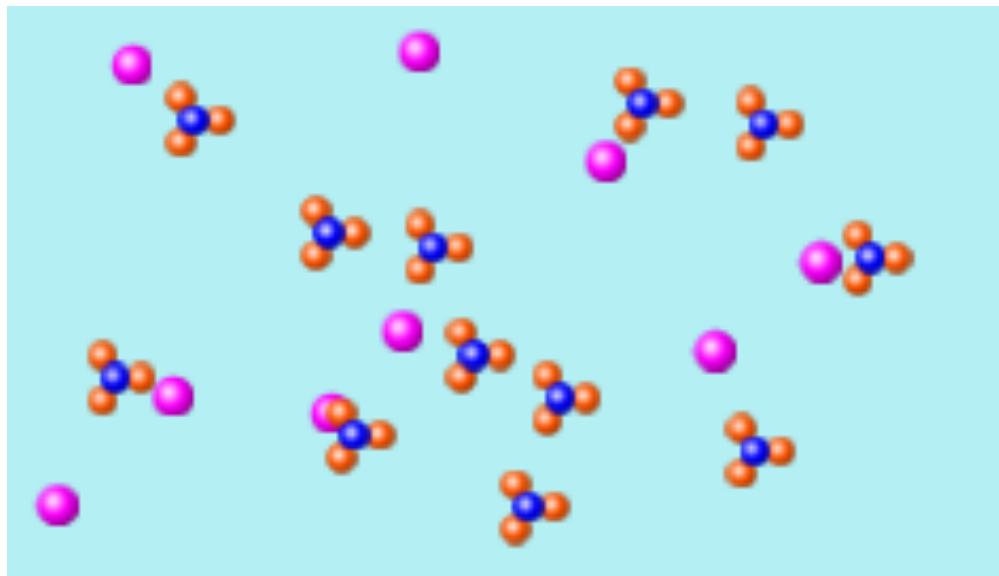
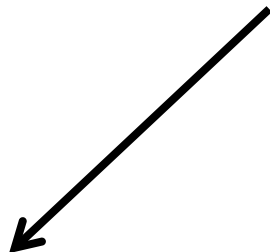
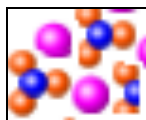


Chemical Name	Chemical Formula	Electrolyte?	Type of bonding
Sodium chloride	NaCl		
Sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>		
Calcium chloride	CaCl <sub>2</sub>		
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>		
Sodium nitrate	NaNO <sub>3</sub>		

Chemical Name	Chemical Formula	Electrolyte?	Type of bonding
Sodium chloride	NaCl	Yes	Ionic
Sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	No	Covalent
Calcium chloride	CaCl <sub>2</sub>	Yes	Ionic (note that more ions means higher conductivity per formula unit vs. NaCl)
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	No	Covalent
Sodium nitrate	NaNO <sub>3</sub>		



What kind of bonding is in this compound before it goes into the water?



- a. Ionic    b. Covalent    **c. Both**    d. Neither

Chemical Name	Chemical Formula	Electrolyte?	Type of bonding
Sodium chloride	NaCl	Yes	Ionic
Sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	No	Covalent
Calcium chloride	CaCl <sub>2</sub>	Yes	Ionic (note that more ions means higher conductivity per formula unit vs. NaCl)
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	No	Covalent
Sodium nitrate	NaNO <sub>3</sub>	Yes	Ionic (between Na <sup>+</sup> and NO <sub>3</sub> <sup>-</sup> ) <b>and</b> Covalent (within the polyatomic ion NO <sub>3</sub> <sup>-</sup> )

# Polyatomic Ions

- Polyatomic ion
  - A group of covalently bonded atoms with an overall net charge
- Oxoanions
  - A common class of polyatomic ion that contains oxygen and another element

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**Description:**

*Depictions of other common polyatomic ions, to expand on the example of a nitrate anion shown in the simulation*

*Ionic compounds*

vs

*Molecular compounds*

**ionic**

Results from attraction of positive  
and negative ions

**Type of  
Bonding**

**covalent**

Results from sharing of electrons  
between atoms

*Ionic compounds*

vs

*Molecular compounds*

**ionic**

Results from attraction of positive  
and negative ions

**Type of  
Bonding**

**covalent**

Results from sharing of electrons  
between atoms

Always dissociates (ionizes)  
Always an electrolyte

**Behavior in  
water**

Usually does not dissociate  
\*exception: ACIDS & BASES

*Ionic compounds*

vs

*Molecular compounds*

**ionic**

Results from attraction of positive  
and negative ions

**Type of  
Bonding**

**covalent**

Results from sharing of electrons  
between atoms

Always dissociates (ionizes)  
Always an electrolyte

**Behavior in  
water**

Usually does not dissociate  
\*exception: ACIDS & BASES

Repeating units

**Structure**

Discrete entities

<i>Ionic compounds</i>	<i>vs</i>	<i>Molecular compounds</i>
<p><b>ionic</b></p> <p>Results from attraction of positive and negative ions</p>	<p><b>Type of Bonding</b></p>	<p><b>covalent</b></p> <p>Results from sharing of electrons between atoms</p>
<p>Always dissociates (ionizes) Always an electrolyte</p>	<p><b>Behavior in water</b></p>	<p>Usually does not dissociate *exception: ACIDS &amp; BASES</p>
<p>Repeating units</p>	<p><b>Structure</b></p>	<p>Discrete entities</p>
<p><b>Formula unit</b></p> <p>Represents the smallest whole number ratio of elements</p>	<p><b>Chemical formula</b></p>	<p><b>Molecular formula</b></p> <p>Represents the actual number of atoms in each discrete molecule</p>

How does the **atomic-level structure** of compounds affect their **observable properties**?

**Conductivity  
in solution**



**Types of  
chemical bonds**

How can we use the **periodic table** to predict the bonding and properties of compounds?



H																		He
Li	Be											B	C	N	O	F	Ne	
<b>Na</b>	Mg											Al	Si	P	S	<b>Cl</b>	Ar	
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr	
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe	
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn	
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn							



**Metal**



**Non-metal**

# Metals, Nonmetals, and Metalloids

- **Metals:**
  - Characteristic luster (shiny!).
  - Good conductors of heat and electricity.
  - Solid at room temperature, except mercury.
- **Nonmetals:**
  - Dull in appearance.
  - Poor conductors of heat and electricity.
- **Metalloids:**
  - Possess some metallic and some non-metallic properties (sometimes depends on the situation!)

Chemical Name	Chemical Formula	Electrolyte?	Type of bonding	Component elements
Sodium chloride	NaCl			<input type="checkbox"/> Metal <input type="checkbox"/> Non-metal
Sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>			<input type="checkbox"/> Metal <input type="checkbox"/> Non-metal
Calcium chloride	CaCl <sub>2</sub>			<input type="checkbox"/> Metal <input type="checkbox"/> Non-metal
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>			<input type="checkbox"/> Metal <input type="checkbox"/> Non-metal
Sodium nitrate	NaNO <sub>3</sub>			<input type="checkbox"/> Metal <input type="checkbox"/> Non-metal

Chemical Name	Chemical Formula	Electrolyte?	Type of bonding	Component elements
Sodium chloride	NaCl	Yes	Ionic	<input checked="" type="checkbox"/> Metal <input checked="" type="checkbox"/> Non-metal
Sucrose	C <sub>12</sub> H <sub>22</sub> O <sub>11</sub>	No	Covalent	<input type="checkbox"/> Metal <input checked="" type="checkbox"/> Non-metal
Calcium chloride	CaCl <sub>2</sub>	Yes	Ionic (note that more ions means higher conductivity per formula unit vs. NaCl)	<input checked="" type="checkbox"/> Metal <input checked="" type="checkbox"/> Non-metal
Glucose	C <sub>6</sub> H <sub>12</sub> O <sub>6</sub>	No	Covalent	<input type="checkbox"/> Metal <input checked="" type="checkbox"/> Non-metal
Sodium nitrate	NaNO <sub>3</sub>	Yes	Ionic (between Na <sup>+</sup> and NO <sub>3</sub> <sup>-</sup> ) <b>and</b> Covalent (within the polyatomic ion NO <sub>3</sub> <sup>-</sup> )	<input checked="" type="checkbox"/> Metal <input checked="" type="checkbox"/> Non-metal

*Ionic compounds*

vs

*Molecular compounds*

**ionic**

Results from attraction of positive and negative ions

**Type of Bonding**

**covalent**

Results from sharing of electrons between atoms

Always dissociates (ionizes)  
Always an electrolyte

**Behavior in water**

Usually does not dissociate  
\*exception: ACIDS & BASES

Repeating units

**Structure**

Discrete entities

**Formula unit**

Represents the smallest whole number ratio of elements

**Chemical formula**

**Molecular formula**

Represents the actual number of atoms in each discrete molecule

metals + non-metals together

**Elements involved**

Only non-metals

# Which compound is ionic?

- A. CO
- B.  $\text{MgF}_2$
- C.  $\text{Al}_2\text{O}_3$
- D. Both CO and  $\text{MgF}_2$
- E. Both  $\text{MgF}_2$  and  $\text{Al}_2\text{O}_3$

# Which compound is ionic?

- A. CO
- B.  $\text{MgF}_2$
- C.  $\text{Al}_2\text{O}_3$
- D. Both CO and  $\text{MgF}_2$

E. Both  $\text{MgF}_2$  and  $\text{Al}_2\text{O}_3$

The periodic table is color-coded: grey for metals and pink for non-metals. Sodium (Na) is highlighted with an orange box, and Chlorine (Cl) is also highlighted with an orange box.

H																			He
Li	Be											B	C	N	O	F	Ne		
Na	Mg											Al	Si	P	S	Cl	Ar		
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr		
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe		
Cs	Ba	La	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn		
Fr	Ra	Ac	Rf	Db	Sg	Bh	Hs	Mt	Ds	Rg	Cn								

Legend:  Metal       Non-metal

A metal combined with a non-metal make an “ionic compound”.