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VCE Chemistry ½
Ionic Compounds [0.4]
Workshop

Section A: Recap

Contour Check

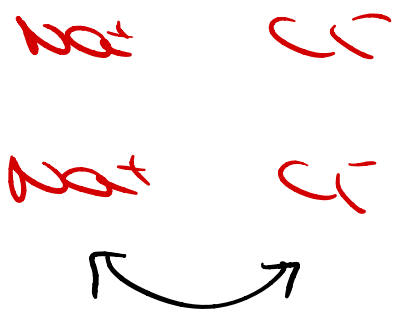
Learning Objective: [1.5.1] - Explain the structure of ionic compounds and be able to draw electron transfer diagrams

Study Design

The formation of ionic compounds through the transfer of electrons from metals to non-metals, and the writing of ionic compound formulas, including those containing polyatomic ions and transition metal ions.

Key Takeaways

- When one atom gives its electron to the other atom, an ionic bond is formed.
- The cation is usually a [metal] / [non-metal] and binds with an anion - usually a [metal] / [non-metal] - to form an ionic compound.
- This bond arises from electrostatic forces between the positive and negative ions. (e.g. F)
- A lattice structure exists between the cations and anions.
- If the ions are not in a 1:1 ratio, the lattice ~~does~~ doesn't look like a 'grid'. They arrange themselves to achieve the most electrostatic attraction between adjacent ions.
- An electron transfer diagram shows how the electrons are transferred when an ionic bond is formed.



Learning Objective: [1.5.2] - Write the formula of simple & complex (containing polyatomic and transition metal ions) ionic compounds and be able to name them

Study Design

Deduction of the formula and name of an ionic compound from its component ions, including polyatomic ions (NH_4^+, OH^-, NO_3^-, HCO_3^-, CO_3^{2-}, SO_4^{2-} and PO_4^{3-}).

Key Takeaways

- A polyatomic ion is an ion which contains multiple atoms.
- A coefficient (a number in front of the compound) represents how many of the **entire compound** there is.
- A subscript (like y in the expression x_y) represents how many of the **individual atoms/polyatomic ions** are there in a compound.
- The electrovalency of an ion is just another name for the **charge** on an ion.
- **Two** ways to determine the charge on an ion with multiple electro-valencies:
  - Roman Numerals.
  - Using Charges from an ionic Compound.
- To name an ionic compound:
  - The cation is written first, followed by the anion
  - Cation names are unaltered
  - Anions typically ending in -ide, or another suffix change.
- To write the formula of an ionic compound:
  - Ensure charges on the cation and anion cancel out to make overall compound neutral

Fe^{2+} Fe^{3+}

Sn^{2+} Sn^{4+}

Cu^{+} Cu^{2+}

Learning Objective: [1.5.3] - Explain the properties of ionic compounds (hardness, high MP/BP, brittleness, electrical conductivity in various states), with reference to their structure and bonding

Study Design

The common properties of ionic compounds (brittleness, hardness, melting point, difference in electrical conductivity in solid and molten liquid states), with reference to the nature of ionic bonding and crystal structure.

Key Takeaways

- Ionic compounds have very high melting/boiling points.
- This is due to the [strong] / [weak] electrostatic attraction present within the lattice structure.
- Ionic compounds are [hard] / [soft] due to their strong lattice structures.
- When the lattice structure is misaligned due to an external force, electrostatic repulsion occurs, resulting in the entire ionic lattice structure to [stay intact] / [shatter], making ionic compounds [brittle] / [malleable].
- In a solid state, ionic compounds comprise ions trapped in a lattice, and [can] / [cannot] conduct electricity.
- In a molten/aqueous state, ionic compounds' ions are free to move and so they [can] / [cannot] conduct electricity.

Space for Personal Notes

Section B: Warm Up (12.5 Marks)

INSTRUCTION: 12.5 Marks. 8 Minutes Writing.

Question 1 (2 marks)

Find the ionic compound which will form between the following atoms.

a. Barium and fluorine. (0.5 marks)

Ba^{2+} F^- BaF_2

b. Calcium and sulphur. (0.5 marks)

Ca^{2+} S^{2-} CaS

c. Calcium and nitrogen. (0.5 marks)

Ca^{2+} N^{3-} Ca_3N_2

d. Aluminium and chlorine. (0.5 marks)

Al^{3+} Cl^- $AlCl_3$

Question 2 (2 marks)

Find the ionic compound which will form between the following atoms and name the compound.

a. Beryllium oxide. (0.5 marks)

Be^{2+} O^{2-}

BeO

b. Copper (II) bromide. (0.5 marks)

Cu^{2+} Br^-

$CuBr_2$

c. Sodium phosphide. (0.5 marks)

Na^+ P^{3-}

Na_3P

d. Aluminium oxide. (0.5 marks)

Al^{3+} O^{2-}

Al_2O_3

Question 3 (2.5 marks)

For the following atoms and ions, name the most likely formula for the resulting compound.

a. Lithium nitride. (0.5 marks)

Li_3N

b. Calcium chloride. (0.5 marks)

$CaCl_2$

c. Potassium phosphate. (0.5 marks)

K_3PO_4

d. Iron (II) bromide. (0.5 marks)

$FeBr_2$

e. Ammonium sulfate. (0.5 marks)

$(NH_4)_2SO_4$

Question 4 (2 marks)

Find the valency for the cation for each of the following.

a. Aluminium chloride. (0.5 marks)

$AlCl_3$

Al^{3+}

b. Ammonium chloride. (0.5 marks)

NH_4^+

c. Magnesium phosphate. (0.5 marks)

$Mg_3(PO_4)_2$

Mg^{2+}

d. Tin (II) nitrate. (0.5 marks)

Sn^{2+}

Question 5 (2 marks)

Write the molecular formula for the following ionic compounds.

a. Iron (III) sulfate. (0.5 marks)

$Fe_2(SO_4)_3$

b. Barium carbonate. (0.5 marks)

$BaCO_3$

c. Zinc (II) nitrate. (0.5 marks)

$Zn(NO_3)_2$

d. Tin (IV) nitrate. (0.5 marks)

$Sn(NO_3)_4$

Question 6 (2 marks)

Explain why metals are always cations when they exist in an ionic compound.

- metals left → achieve a full shell easier by losing e^-, rather than gaining
- metals have a low ion charge → electrons can be lost easily

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Section C: Ramping Up (15 Marks)

INSTRUCTION: 15 Marks. 11 Minutes Writing.

Question 7 (1 mark)

Which of the following is considered an ionic compound?

A. H_2O

B. CO_2

C. CH_4

D. $CaCl_2$

Question 8 (6 marks)

Consider the compound $(NH_4)_2CO_3$.

a. Does this compound have three ions of CO? Explain your answer. (2 marks)

No. No 3 → subscript → applies to the oxygen only & not the whole (CO)

b. What is the name of this compound? (1 mark)

ammonium carbonate.

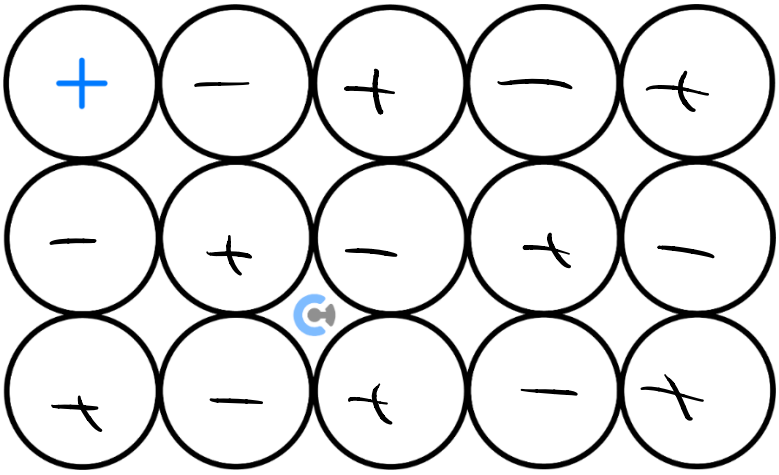
c. In the lesson, it was covered that typically, ionic compounds consist of metals bonding with nonmetals. However, this compound does not contain any metal at all. Suggest a possible explanation as to why this is still considered an ionic compound. (3 marks)

- ionic compound → cation & anions.
- NH_4^+ cation, CO_3^{2-} anion
- by these are attracted via electrostatic force → ∴ its still an ionic bond.

Question 9 (3 marks)

Sodium chloride is an example of an ionic compound with a lattice structure.

a. Complete the charges on the ions below to represent an ionic lattice like the one that sodium chloride adopts. (1 mark)



b. Sodium chloride has a melting point of about 800°C. Explain this with reference to the structure and bonding in sodium chloride. (2 marks)

- NaCl → strong & highly packed lattice
- strong electrostatic forces → lots of energy to be broken.

Question 10 (5 marks)

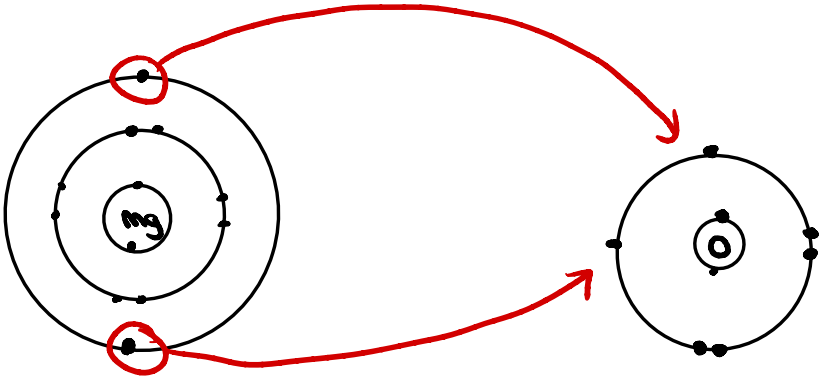
The following compound is to be investigated:

MgO

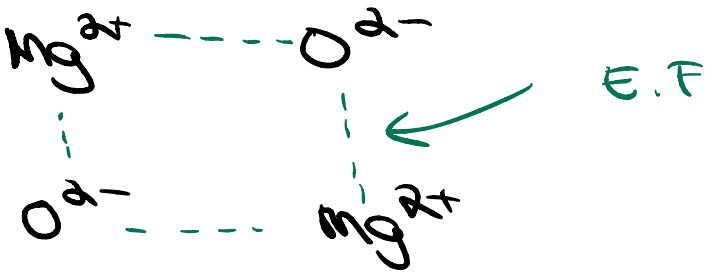
a. Name the molecule. (1 mark)

Magnesium Oxide

b. Draw the electron transfer diagram for the formation of this ionic compound from magnesium and oxygen. (2 marks)



c. Draw the lattice structure of this MgO, including at least 4 atoms in total. Label the electrostatic attraction. (2 marks)



Section D: Getting Trickier I (12 Marks)

INSTRUCTION: 12 Marks. 10 Minutes Writing.

Question 11 (8 marks)

Consider a molecule of $NaNO_3$.

a. Name the compound $NaNO_3$. (1 mark)

_____

b. Now, consider a molecule of HBr, state what bond holds this molecule together. (1 mark)

_____

c. What is the molecular geometry of HBr, and is it polar or non-polar? (2 marks)

_____

_____

d. Explain what happens to the HBr molecule overall, in terms of polarity. (2 marks)

_____

_____

_____

e. Hence or otherwise, of the two molecules, which one do you think will exhibit a stronger charge with itself? Justify your answer. (2 marks)

_____

_____

_____

Question 12 (4 marks) Al^{3+} O^{2-}

Consider a compound aluminium (III) oxide.

a. Give the molecular formula of this compound. (1 mark)

Al_2O_3

b. Aluminium oxide is a common material found in ceramic items like bowls, spoons and more. These objects are commonly used to contain food when we eat it. Suggest a possible reason as to why this is preferred compared to an iron bowl. (3 marks)

- metals have a sea of delocalised e⁻
→ allows them to be thermally conductive
- however ionic compounds → less conductive
∴ will retain heat in food better
by conducting less of the thermal energy.

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Section E: Getting Trickier II (15 Marks)

INSTRUCTION: 15 Marks. 14 Minutes Writing.

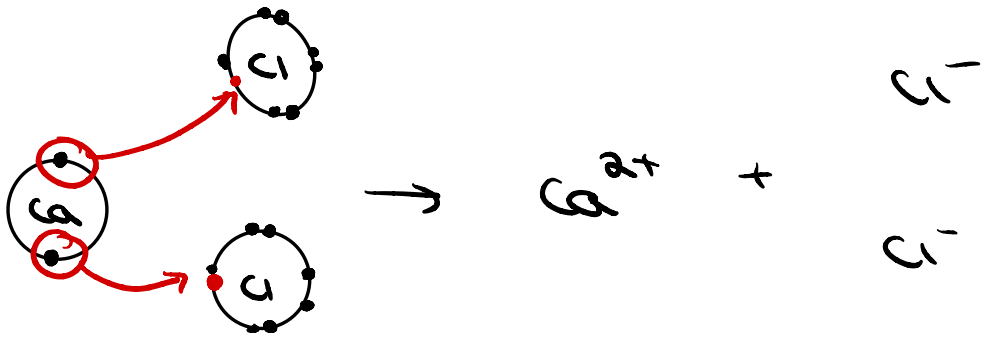
Question 13 (6 marks)

Eesha is investigating calcium chloride.

a. Write the molecular formula for calcium chloride. (1 mark)

$CaCl_2$

b. Draw the electron transfer diagram between calcium and chloride. You only need to draw the outer shell electrons. (3 marks)



c. Draw the structure of calcium chloride, including at least 4 calcium atoms in the diagram. Label the electrostatic attraction. (2 marks)

$CaCl_2$ →

Question 14 (9 marks)

A scientist is observing the changes within objects when heat is applied to them.

a. They observe that when a ceramic bowl made of $CaCO_3$ is heated up intensely, it just shatters. State this property. (1 mark)

brittle

b. The scientist observes that when a bowl constructed from Cu is subject to the same temperature, it simply melts. Explain the difference in observations that the scientist observed, with reference to their properties. (4 marks)

• Cu → metal → sea of delocalised e^- → cations can shift & electrons can e^- shift ∴ electrostatic forces are maintained

• $CaCO_3$ → ionic bonding → cations & anions in a lattice → when heat is applied → ions shift & repel ∴ shatters.

c. As such, if this scientist is working for a company that wants to produce cookware like a frying pan, which of the two materials above would you recommend? Briefly justify your answer. (2 marks)

Copper → sea of delocalised e^- → thermally conductive

• $CaCO_3$ → shatters when heated.

d. The scientist then observes a contradiction. They find that ceramic is often also used for the ironing plates of household irons. Suggest a potential reason as to why ceramic is used in irons if it has the potential to crack, as shown above. (2 marks)

- Heat is not high enough.
- Ceramics will maintain shape when as they are not malleable.

Let's take a BREAK!

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Section F: VCAA-Level Questions I (9 Marks)

INSTRUCTION: 9 Marks. 30 Seconds Reading. 8 Minutes Writing.

Question 15 (9 marks)

Calcium carbonate is a common mineral found in rocks and is the main component of the shells of marine organisms.

a. What is the ionic formula for calcium carbonate? Explain what this formula means in terms of the structure of calcium carbonate. (2 marks)

$CaCO_3$

↳ 1:1 ratio → alternating cations & anions → lattice

b. What property of ionic compounds makes them suitable to be used as shells in marine organisms? Justify your response. (2 marks)

Hard → cations & anions are tightly packed in lattice → strong electrostatic forces

Calcium carbonate can be heated to release calcium oxide and carbon dioxide.

c. Write the ionic formula for calcium oxide. (1 mark)

CaO

Ca^{2+} O^{2-}

d. This decomposition occurs at temperatures greater than 840°C. Why are very high temperatures needed? Justify your response. (2 marks)

- Strong ionic bond in lattice
- A energy is need to break the ionic bond.

e. Is the following equation involving calcium carbonate a double displacement reaction? Justify your answer. (2 marks)

$$CaCO_3(s) + CO_2(g) + H_2O(l) \rightarrow Ca(HCO_3)_2(aq)$$

NO.

AB + CD → AD + BC

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Section G: Multiple Choice Questions (9 Marks)

INSTRUCTION: 9 Marks. 9 Minutes Writing.

Question 16 (1 mark)

Which of the following best explains why ionic compounds have very high melting and boiling points?

A. No delocalised sea of electrons, resulting in tighter packing of atoms.

B. The ions form strong electrostatic attraction between one another, resulting in a strongly held ionic lattice.

C. The ionic lattice is held together by strong nuclear forces between atoms.

D. Electrons are continually transferred from the cations to the anions, resulting in strong electrostatic attractions.

Question 17 (1 mark)

Which of the following is a property shown by ionic compounds?

A. They conduct electricity generally.

B. They usually have a tetrahedral molecular geometry.

C. They conduct electricity in a liquid state only.

D. They can withstand external forces without shattering.

Question 18 (1 mark)

Which of the following properties belongs to that of metals, but NOT ionic compounds?

A. Thermal conductivity.

B. Ductility.

C. Electrical conductivity.

D. Relatively strong intramolecular bonding.

Question 19 (1 mark)

Which of the following properties belongs to that of an ionic compound and a metal?

A. Relatively high melting and boiling points, compared to covalent molecules.

B. The existence of free moving charges.

C. Electrical conductivity in the solid state.

D. Sublimation points.

Question 20 (1 mark)

H F

Which of the following best explains the reason why HF is not considered an ionic compound?

A. Hydrogen is not a metal, and by definition metals and nonmetals make up an ionic compound.

B. The Hydrogen-Fluorine bond does not have a large enough difference in electronegativity so that the electrons would be completely transferred.

A B

C. As HF is polar, it is not considered ionic.

D. The hydrogen is preventing the transfer of electrons as it will have no electrons otherwise.

Question 21 (1 mark)

Which of the following categories of elements are the most likely to exhibit multiple electrovalencies?

A. Halogens

B. Alkali Metals

C. Alkaline Earth Metals

D. Transition Metals

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Question 22 (1 mark)

Which of the following pairs of ions would form an ionic compound with a 1: 2 ratio respectively between the cation and the anion?

A. Beryllium and Oxygen ✗

B. Sodium and nitrate ✗

C. Calcium and Chlorine

D. Magnesium and Phosphate

Question 23 (1 mark)

Ionic compounds are formed between elements that have a large difference in:

A. Electronegativity

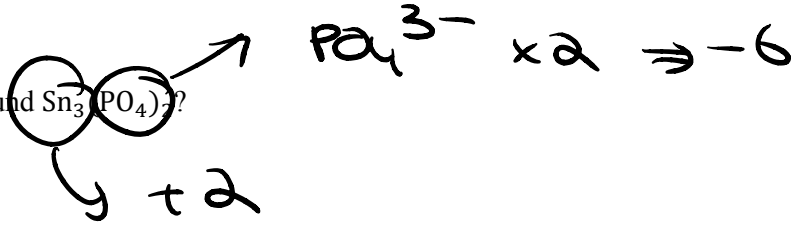
B. Isotopic Number

C. First ionisation energy

D. Atomic Number

Question 24 (1 mark)

What is the valency of tin in the compound $Sn_3(PO_4)_2$?



A. +1

B. +2

C. +3

D. +4

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Section H: VCAA-Level Questions II (13 Marks)

INSTRUCTION: 13 Marks. 30 Seconds Reading. 12 Minutes Writing.

Question 25 (8 marks)

Salts of fluorine are often added to the municipal water supply and toothpaste in order to prevent dental cavities.

a. Fluorine is toxic but the fluoride ion is safe for human consumption. Explain the difference between a fluorine atom and the fluoride ion with respect to their electron configurations and properties. (2 marks)

Fluoride ions are essential for the production of fluorapatite which is found in tooth enamel. The ionic formula is $Ca_5(PO_4)_3F$.

b. Name and identify all ions present in fluorapatite and their charges. What is the ratio of these ions in fluorapatite? (4 marks)

c. What properties of fluorapatite make it suitable to function as tooth enamel? Justify your answer. (2 marks)

Question 26 (5 marks)

Megan is investigating three newly discovered elements, X, Y and Z, which behave as cations in ionic compounds. She knows that the charge of different ions can be determined by the ratio of atoms of each element in an ionic compound. In order to find out the charges, she is able to weigh the mass of each element present and, after a few calculations, determine the unknown charge of the cation.

a. What type of data is collected? (1 mark)

b. What is the independent and dependent variable? (2 marks)

c. The masses she recorded in her logbook were based on a scale that wasn't calibrated. What type of error is this and how could her data be corrected? (2 marks)

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