Matter and chemical bonding slide deck

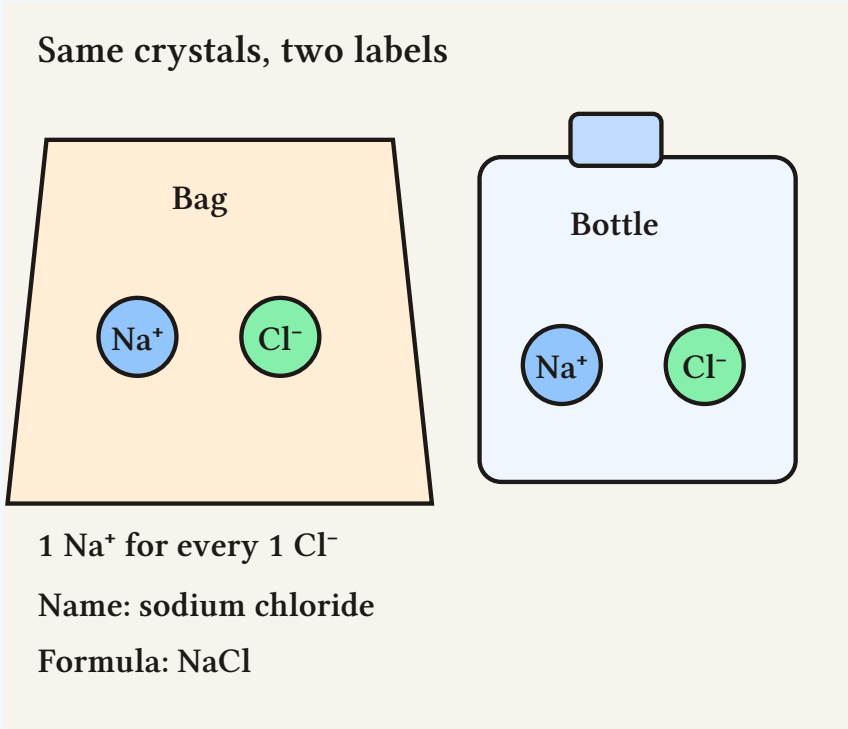
Chemistry 20

Unit A: Matter and chemical bonding

Ionic names and ratios

Two labels for the same white crystals

- A road-salt bag may say sodium chloride, while a lab bottle of the same crystals says NaCl.
- The name and the formula describe one ratio of sodium ions and chloride ions.



Ionic names and formulas

- The cation name comes first, then the anion, and a multivalent metal carries a Roman numeral for its charge.
- Subscripts are the smallest whole numbers that make the total positive charge equal the total negative charge.

Key terms

ionic compound

A pure substance made from positive ions and negative ions held in a fixed ratio. (NaCl)

formula unit

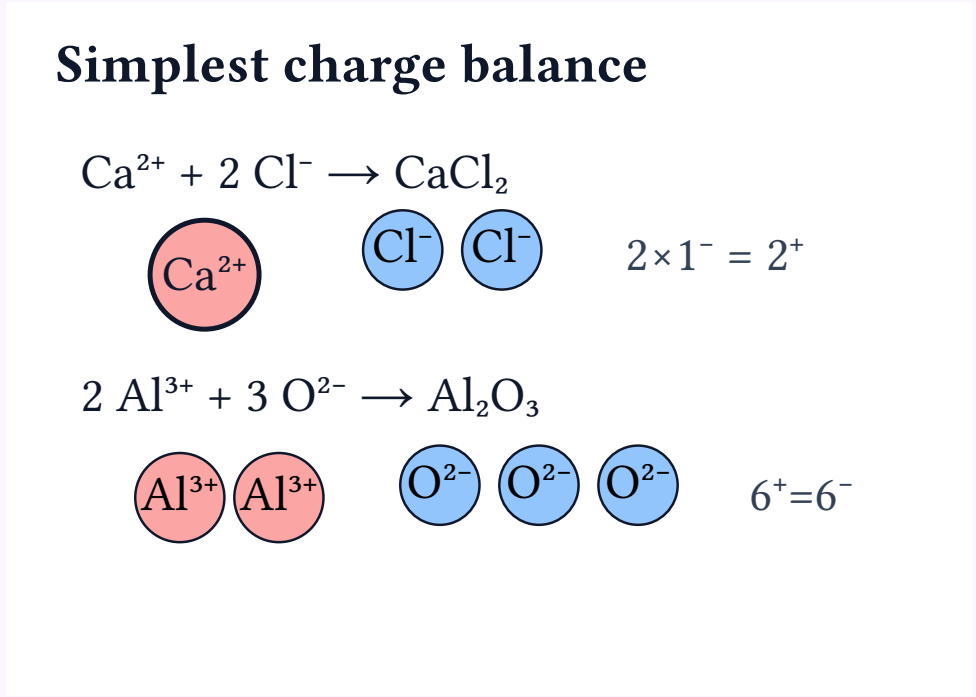
The simplest whole-number ratio of ions that represents an ionic compound. ($CaCl_2$)

net charge

The sum of all ion charges in a formula unit. A stable ionic formula has a net charge of zero. (0)

Simplest charge balance

- Calcium ion is Ca^{2+} and chloride is Cl^{-}, so two chlorides accompany each calcium in $CaCl_2$.
- Aluminum ion is Al^{3+} and oxide is O^{2-}, so the smallest balance is Al_2O_3.



From iron(III) chloride to $FeCl_3$

- Iron(III) means Fe^{3+}, and chloride means Cl^-.
- Three chloride ions cancel one iron(III) ion, so the formula unit is $FeCl_3$.

Completing aluminum sulfate

- Aluminum is Al^{3+} and sulfate is SO_4^{2-}.
- The smallest whole-number balance uses two aluminum ions and three sulfate ions.

Names and ratios

- Name CuO and Cu_2O with Roman numerals that match the copper charge.
- Write the formula unit for calcium nitrate and show that its charges sum to zero.

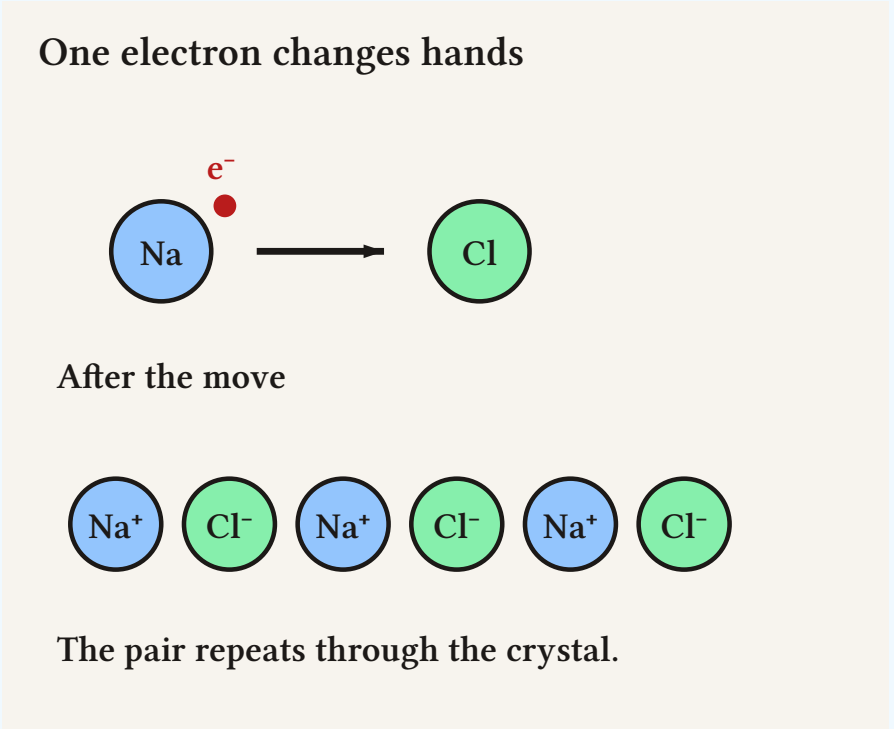
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Unit A: Matter and chemical bonding

Electron transfer and the ionic bond

Table salt starts as a one-electron move

- In a salt crystal, one outer electron leaves a sodium atom and joins a chlorine atom.
- After that move you have Na^+ and Cl^-, and the crystal repeats that pair.



Four labels for one transfer

- The outer-electron count decides how the bond in NaCl forms.
- Electronegativity is how strongly an atom pulls bonding electrons. Fluorine is highest, at 4.0.

Key terms

valence electron

An outer electron counted from the main-group column before a dot diagram is drawn. (group number)

electronegativity

A unitless Pauling-scale value for an atom's pull on bonding electrons. The values rise toward fluorine. (Pauling scale)

ionic bond

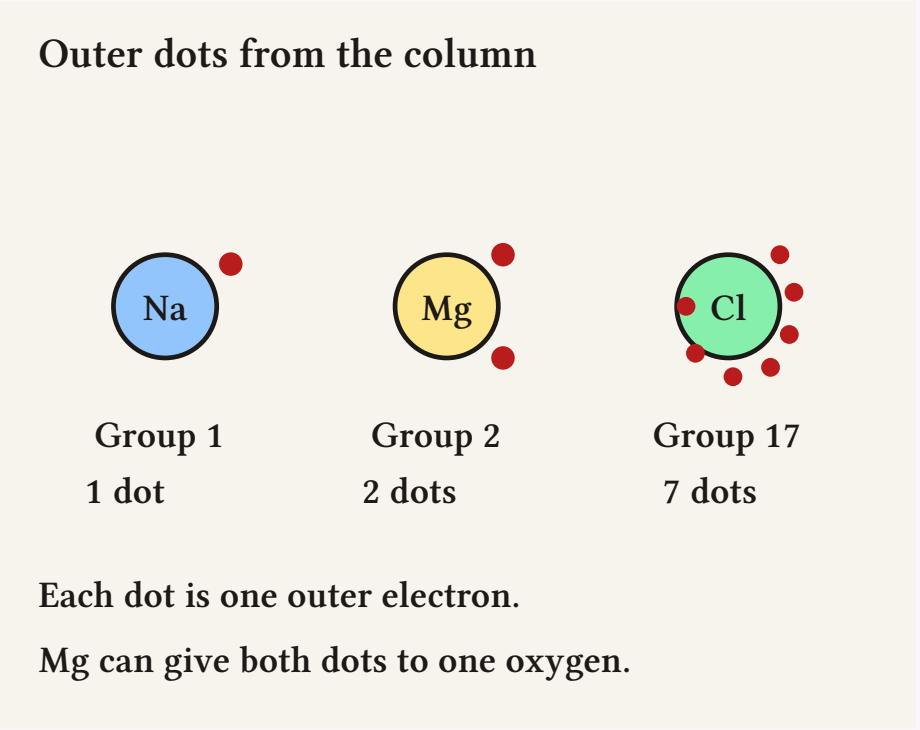
The pull that a positive ion and a negative ion exert on each other at the same time. (Na^+ with Cl^-)

intramolecular force

The bonding pull that operates inside one formula unit. (inside NaCl)

Columns choose the dot count

- Group 1 is drawn with one dot and group 17 is drawn with seven dots.
- Group 2 is drawn with two dots, so magnesium can supply two electrons to one oxygen atom.



Sodium’s dot lands on chlorine

- Start-of-transfer counts are one dot for sodium and seven dots for chlorine.
- End-of-transfer symbols are Na^{+} beside an eight-dot Cl^{-}.

Potassium hands one dot to bromine

- Potassium belongs to the same column as sodium, so the dot count is one.
- Bromine belongs to the same column as chlorine, so the dot count is seven.

Two melting points

- Sodium chloride melts at 801 °C and potassium iodide melts at 681 °C.
- The rounded Pauling differences are 2.1 for the chloride and 1.7 for the iodide.

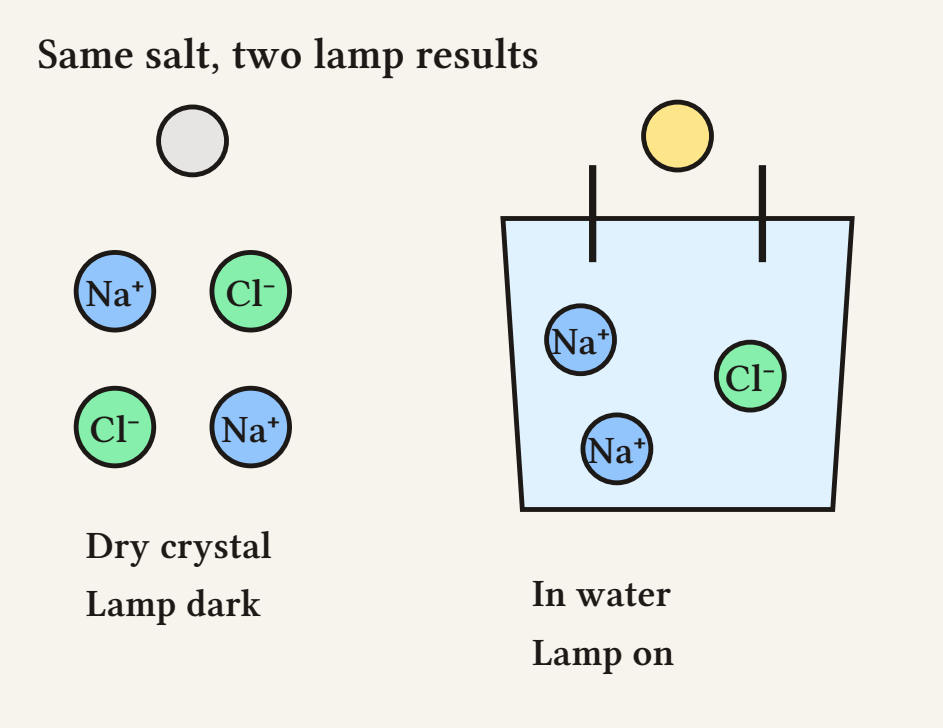
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Unit A: Matter and chemical bonding

Ionic lattices and their properties

The same crystals, two lamp results

- Dry sodium chloride can sit on a conductivity probe while the lamp stays dark.
- A scoop of those same crystals dissolved in water can close the circuit.



Properties that come from a repeating array

- A grid of ions melts high and lights a lamp only after the ions can move.
- Household cases include table salt, calcium materials in bone and dairy, and baking soda.

Key terms

crystal lattice

A repeating three-dimensional array of positive ions and negative ions. (NaCl array)

melting point

The temperature at which the solid lattice gives way to a liquid, reported here in degrees Celsius. (801 °C)

solubility

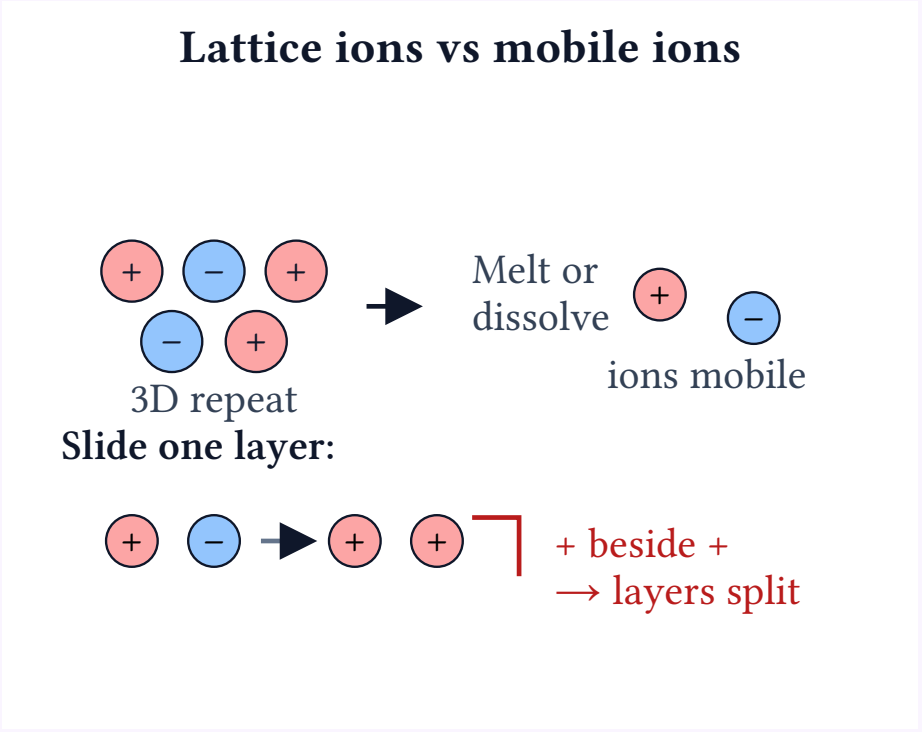
The mass of a solid that dissolves in a stated mass of water at a stated temperature. (36 g in 100 g water)

brittleness

The tendency of an ionic crystal to split when shifted layers bring like charges together. (a tap splits salt)

Fixed ions and free ions

- A lattice is a 3D repeat, and melting or dissolving is what lets ions leave their seats.
- A shifted layer puts positives opposite positives, so the crystal splits apart.



A plan that starts with the label

- The written plan names solubility, the lamp test, and a cited melting point.
- The label is read, and goggles go on, before a scoop is taken.

A two-row lamp table

- Row A is dry sodium chloride and the lamp stays off.
- Row B is 5.0 g of that solid dissolved in 100 mL of distilled water and the lamp lights.

Kitchen lattices

- Name NaCl, calcium materials, and $NaHCO_3$ as ionic arrays people meet outside the lab.
- Match one property of NaCl to the repeating charges.

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Unit A: Matter and chemical bonding

Bonding research and communication

Spark plugs and computer chips

- An aluminum oxide insulator in a spark plug is fired from a lattice that researchers already mapped.
- A silicon wafer is doped in a factory using what researchers learned about electrons in that crystal.



Bonding research report

- Three useful solids show research and manufacturing correcting each other.
- The drawing and the measured number have to describe the same ion grid.

Key terms

semiconductor

A solid, such as silicon, whose controlled conductivity comes from research on electrons in the crystal and from careful factory additions. (doped silicon)

ceramic

A solid such as aluminum oxide that is shaped and fired, with properties that follow from its lattice. (Al_2O_3 insulator)

composite material

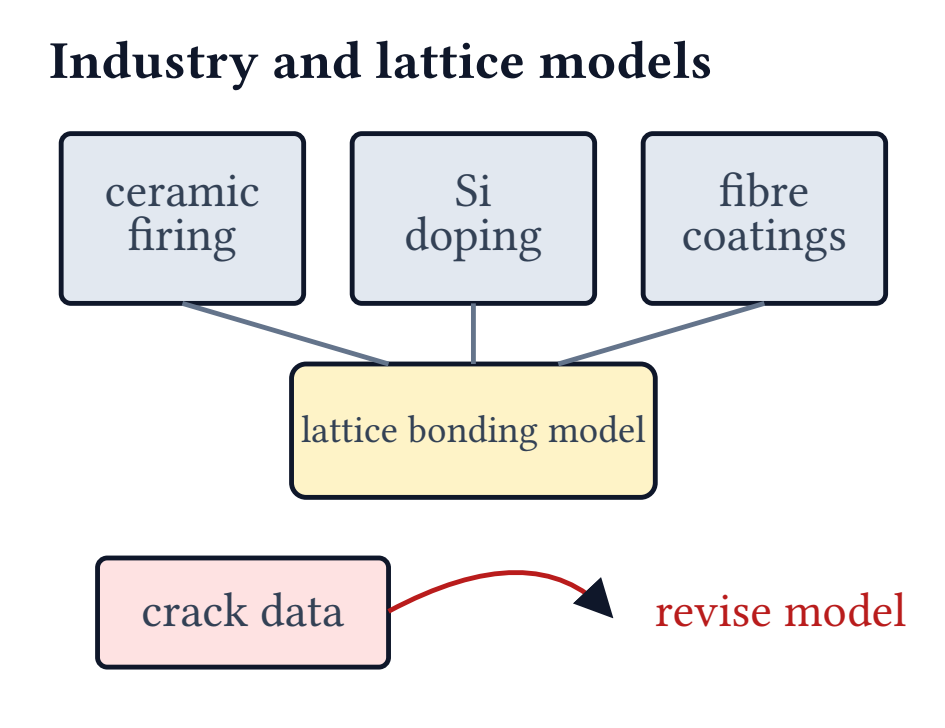
A manufactured solid that combines parts, such as glass fibres in a polymer, so the product has a property neither part has alone. (fibre plus binder)

significant digits

The digits in a measured or reported value that communicate its precision, such as the three digits in 801. (801 has three)

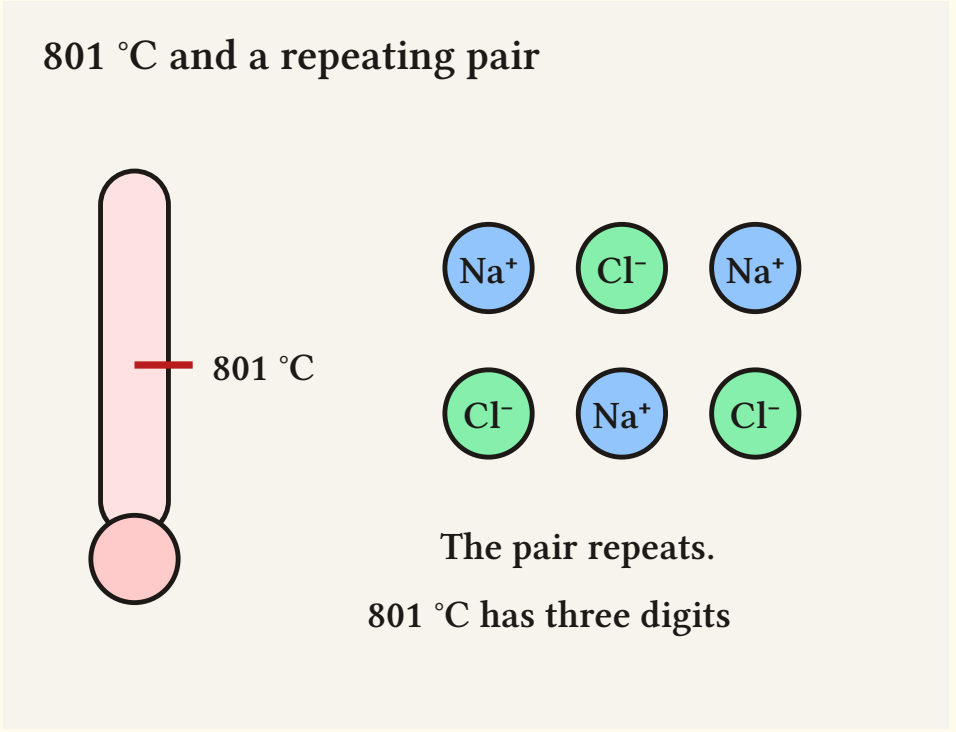
Industry and lattice models

- Ceramic firing, silicon doping, and fibre coatings are factory choices tied to bonding evidence.
- A new crack measurement can send the bonding model back for revision.



801 °C and a shared dash

- The reported melt 801 °C contains three significant digits.
- A drawing of one Na-Cl dash is rewritten as charged particles in a repeat.



A second model and a second number

- A classmate writes NaCl as a molecule because the formula has two symbols.
- The same classmate records the melt as 801.0 °C.

Evidence and the label

- A coordination question can be answered from a structure without launching a product.
- A panel load question is settled by a test on that product.

Image credits

User:Industry shill, Spark plug guts, public domain

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Unit A: Matter and chemical bonding

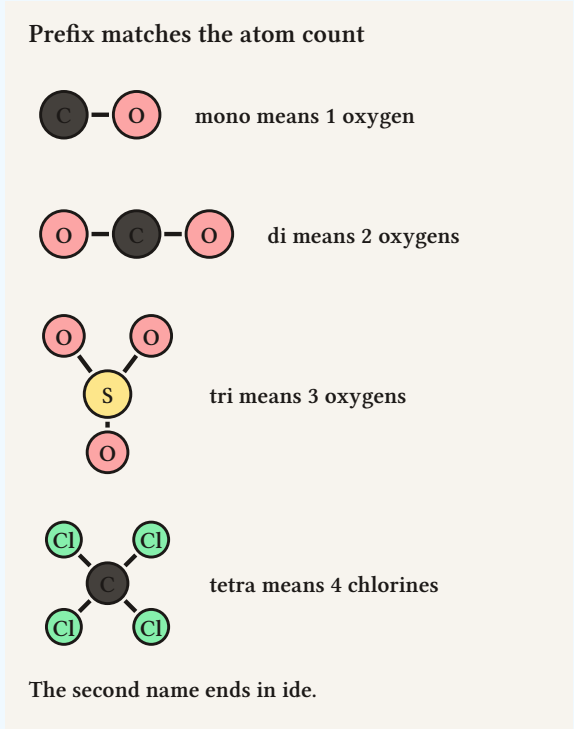
Molecular names and shared pairs

Two nitrogen formulas are two substances

- N_2O_4 names a molecule with two nitrogen atoms and four oxygen atoms.
- NO_2 names a different molecule, so dividing the first formula changes the substance.

Prefixes speak the atom count

- The prefixes mono, di, tri, and tetra mean one, two, three, and four atoms.
- Penta and hexa extend the same idea to five and six, and the second element ends in ide.



Key terms

molecular formula

A formula that counts the atoms of each element in one molecule, without dividing down to a smaller ratio. (N_2O_4)

covalent bond

A shared pair of electrons that holds two atoms together in a molecule. (one shared pair)

multiple bond

A double or triple bond, meaning two or three shared pairs between the same two atoms. (O_2 and N_2)

numerical prefix

A syllable such as mono, di, tri, tetra, penta, or hexa that states an atom count in a binary molecular name. (di means two)

The subscript is an atom count

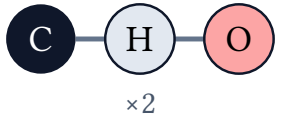
- Each subscript multiplies only the element it follows, unless parentheses say otherwise.
- Glucose, $C_6H_{12}O_6$, keeps its full formula when the molecule itself is meant; CH_2O is only the simplest ratio.

Subscript = atom count

$C_6H_{12}O_6$ glucose (full molecule)

Each molecule: 6 C, 12 H, 6 O

CH_2O (simplest ratio only)



1:2:1 ratio only; not full glucose

Oxygen shares two pairs

- A covalent bond is one shared pair.
- The bond in O_2 is a double bond, which is two shared pairs.

Nitrogen shares three pairs

- Each nitrogen atom starts with 5 valence electrons.
- The bond in N_2 is a triple bond, a multiple bond of three shared pairs.

Carbon dioxide

- The name carbon dioxide omits mono on carbon and uses di for two oxygen atoms.
- Each carbon-oxygen link in CO_2 is a double bond.

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Unit A: Matter and chemical bonding

Lewis structures and the bonding continuum

A line formula can hide electrons

- H-O-H shows two shared pairs and leaves the rest of oxygen’s electrons unstated.
- A full pair drawing puts those remaining electrons on the oxygen atom as lone pairs.

Electron pairs and the continuum

- C, N, O, and F are checked for 8 electrons, and H is checked for 2.
- NaCl, HCl, and Cl_2 will sit at three different positions on one sharing scale.

Key terms

Lewis structure

A drawing that places every valence electron as a bonding pair or a lone pair so each required octet or duet is visible. (pairs around atoms)

structural formula

A formula that uses a line for each shared pair, as in H-O-H or O=C=O. (one line, one pair)

octet

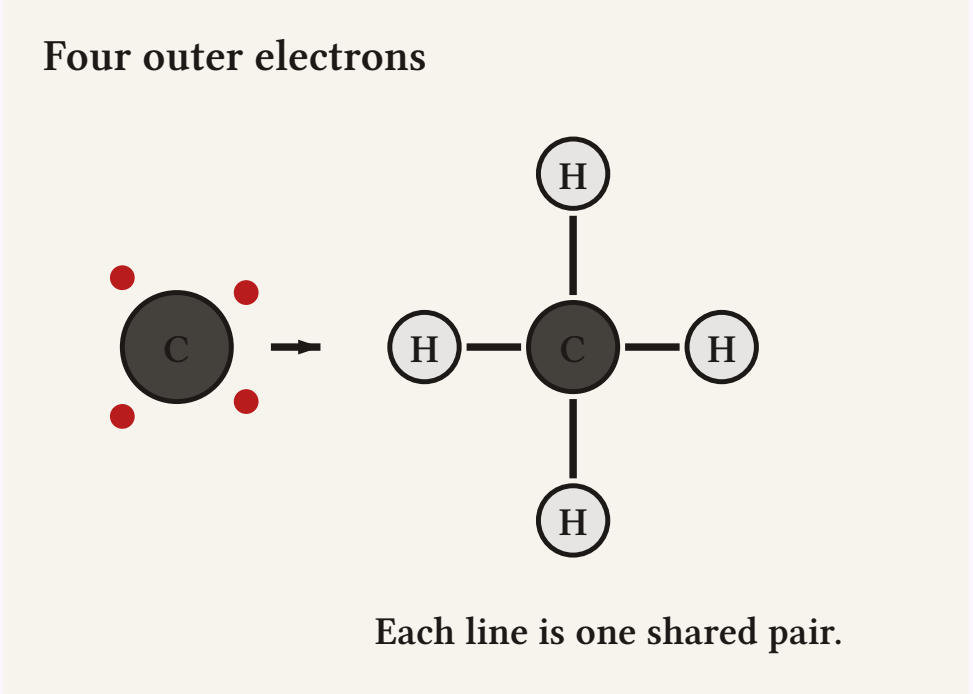
Eight valence electrons around C, N, O, or F in the finished drawing. (8 electrons)

bonding continuum

The range from complete electron transfer, through unequal sharing, to equal sharing. (NaCl, HCl, Cl_2)

Four outer electrons become four Lewis pairs

- Carbon has four outer electrons. In methane each one pairs with a hydrogen electron, so you draw four bonding pairs.
- Each Lewis pair is two electrons, drawn as two dots or one line, and each hydrogen holds only that pair.



Water and carbon dioxide side by side

- Water uses two bonding pairs and two lone pairs on oxygen.
- Carbon dioxide uses two double bonds and two lone pairs on each oxygen.

Ammonia on the model kit

- Nitrogen starts with 5 valence electrons and ammonia adds three hydrogens.
- The model needs three sticks and one lone-pair flag on nitrogen.

Three positions

- NaCl sits at complete transfer, HCl at unequal sharing, and Cl_2 at equal sharing.
- The Pauling differences for those three cases are 2.1, 0.9, and 0.

Chemistry 20

Unit A: Matter and chemical bonding

Molecular shapes and polarity

Two oxygen compounds, two outlines

- Carbon dioxide is a straight three-atom line.
- Water is a two-bond bend, so the outline is bent.

Five outlines and one polarity decision

- The outlines to name are linear, bent, tetrahedral, trigonal pyramidal, and trigonal planar.
- Polarity is decided after the outline and the bond pulls are both known.

Key terms

VSEPR

Valence shell electron pair repulsion, the idea that electron domains around a central atom stay as far apart as they can. (domains repel)

electron domain

One lone pair or one bonding region. A double bond counts as one domain, the same as a single bond. (one region)

molecular polarity

A molecule's overall separation of charge, decided by both its shape and whether the bond pulls cancel. (shape plus pulls)

bond dipole

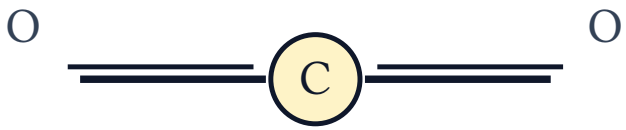
The pull along one bond when the two atoms share electrons unequally. (partial charges)

Electron regions and shape

- A double bond counts as one domain, the same as a single bond.
- BeH_2 is linear too, and the practice case with a full octet on the central atom is CO_2.

Domains and shape

Double bond = 1 domain



CO_2 linear (2 domains)

BeH_2 linear too (2 domains)

Central atom keeps full octet in CO_2

Five molecules, five names

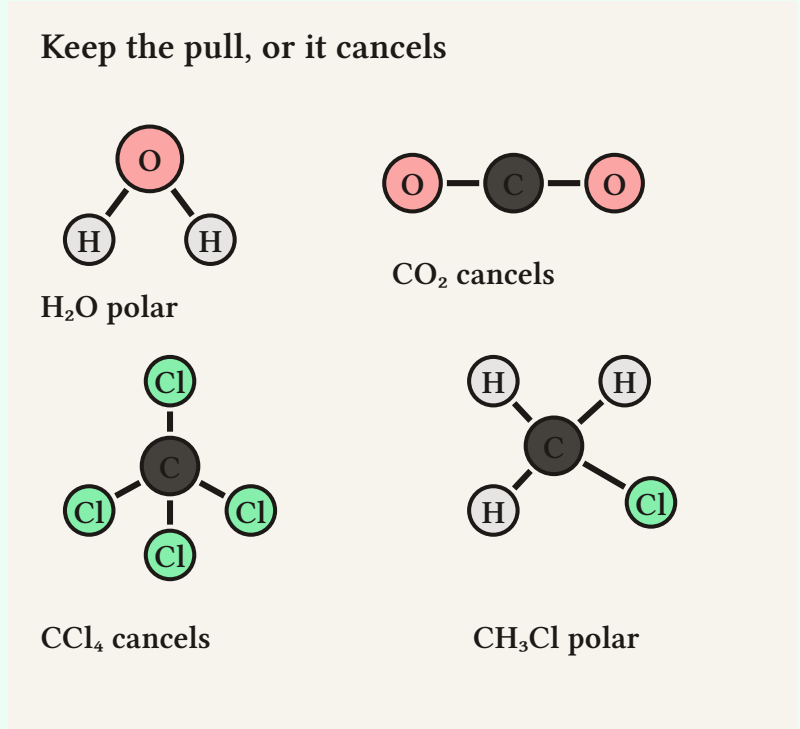
- CO_2 is linear, CH_4 is tetrahedral, and BF_3 is trigonal planar.
- NH_3 is trigonal pyramidal and H_2O is bent.

One new planar molecule

- Formaldehyde, H_2CO, has three domains around carbon.
- The double bond to oxygen counts once in that domain total.

Review

- Water is polar, and carbon dioxide is a nonpolar molecule.
- CCl_4 is nonpolar and CH_3Cl is polar.



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Unit A: Matter and chemical bonding

Intermolecular forces and boiling points

The heavier gas boils colder

- Hydrogen sulfide has the larger molar mass and the much lower boiling point.
- Water boils at 100.0 °C while hydrogen sulfide boils at −60.3 °C.

Three attractions, then the temperatures

- Every molecule has a weak pull from a shifting electron cloud.
- Melting, boiling, and the energy to melt or boil are the property clues.
- Polar molecules add a pull between charged ends. Hydrogen on N, O, or F adds a stronger pull.

Key terms

London forces

Attractions from temporary uneven electron clouds. They act in every molecule and grow stronger as the electron count rises. (temporary dipoles)

dipole-dipole force

An attraction between the permanent partial charges of neighbouring polar molecules. (permanent dipoles)

hydrogen bonding

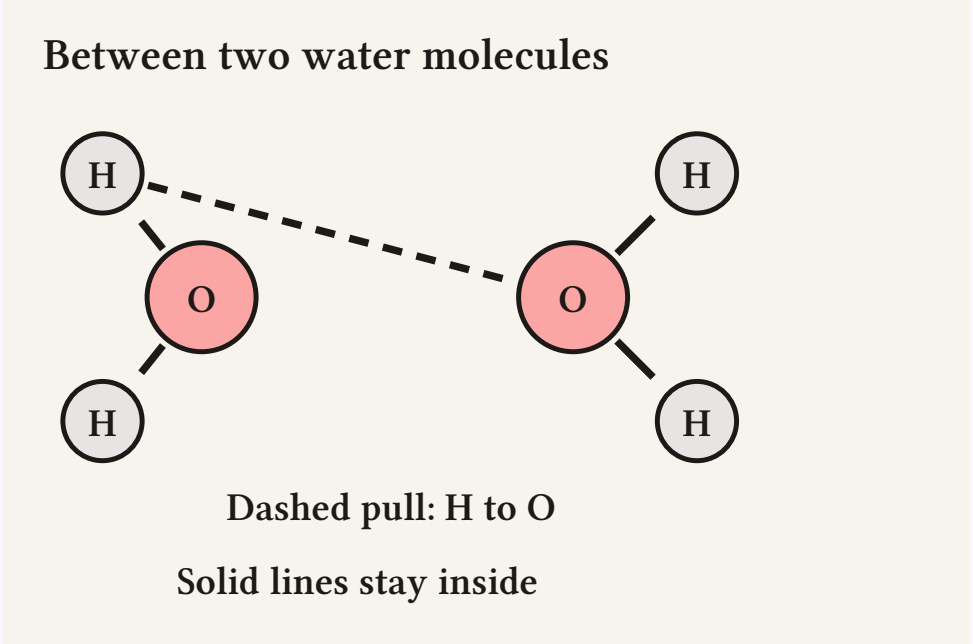
The attraction from a hydrogen attached to N, O, or F toward a lone pair on N, O, or F in a neighbouring molecule. (H with N, O, or F)

enthalpy of vaporization

The energy needed to vaporize one mole at the boiling point, measured here in kilojoules per mole. (kJ/mol)

The dashed line is between molecules

- A dashed line joins a hydrogen on one water molecule to the oxygen on the next water molecule.
- The solid lines inside one molecule remain the shared pairs.



A hypothesis for three alkanes

- Methane, ethane, and propane are a related nonpolar series.
- The hypothesis says the boiling point rises as the temporary-cloud attraction increases.

Butane continues the count

- Butane, C_4H_{10}, has 34 electrons.
- Its boiling point is −0.5 °C, still at the same pressure of 101.325 kPa.

Energy to boil

- Water's enthalpy of vaporization is 40.7 kJ/mol and hydrogen sulfide's is 18.7 kJ/mol.
- Ice's enthalpy of fusion is 6.01 kJ/mol at 0 °C.

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Unit A: Matter and chemical bonding

Molecular substances in daily life

Sugar and a cleaner share a pattern

- Table sugar is sucrose, formula $C_{12}H_{22}O_{11}$, a molecular solid in food.
- Some cleaners use ethanol, C_2H_6O, a small molecular liquid.



Materials and evidence

- Resins, rubber-like plant materials, polymers, and solvents are molecular cases outside the beaker.
- A melting plan needs a hypothesis, a thermometer, a conductivity check, and a graph review.

Key terms

polymer

A long molecule built by linking many repeating units, such as polyethylene built from ethene units of formula C_2H_4. (repeating chain)

solvent

A substance, often a liquid, that dissolves another substance. Ethanol and propanone are molecular examples. (C_2H_6O)

nanotechnology

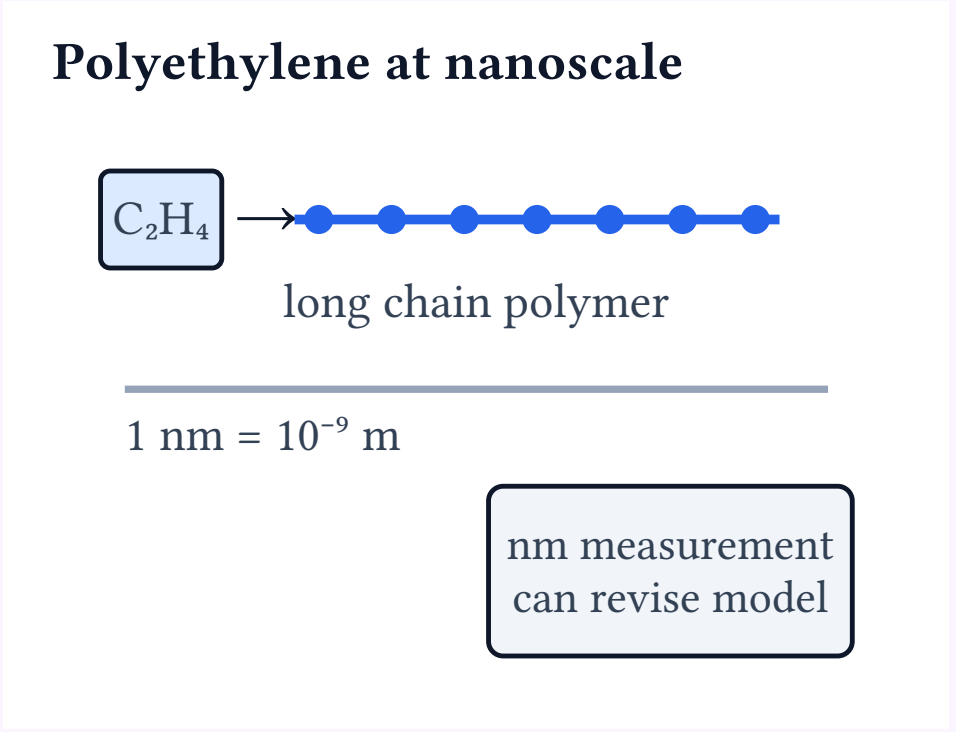
Work at the scale of a nanometre, one billionth of a metre, where new measurements can revise a model of how atoms are arranged. (10^{-9} m)

hypothesis

A stated expectation that names the pattern you will compare with measurements. (prediction before data)

Molecular materials at the nanoscale

- Polyethylene is a long chain made by linking ethene units, each C_2H_4.
- A nanometre is 10^{-9} m, and a measurement at that scale can revise a model.



A melting plan with the label first

- The hypothesis says stearic acid melts higher than lauric acid because the longer chain has stronger London forces.
- The label is read, and goggles go on, before the water bath is started.

Boiling point plot

- The horizontal axis is the carbon count: 1, 2, and 3.
- The vertical axis is boiling point: −161.5 °C, −88.6 °C, and −42.1 °C.

Someone else’s graph

- Another group’s graph is judged against the same three temperatures.
- Different readers can notice different faults, and the comparison improves the trend model.

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