Chemistry 20 full slide deck

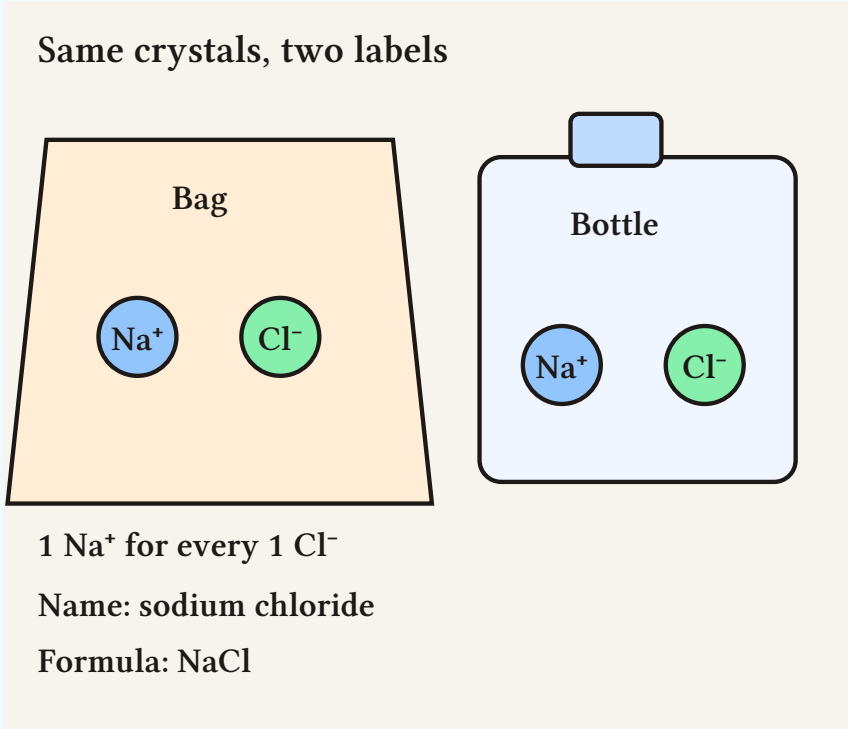
Chemistry 20

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

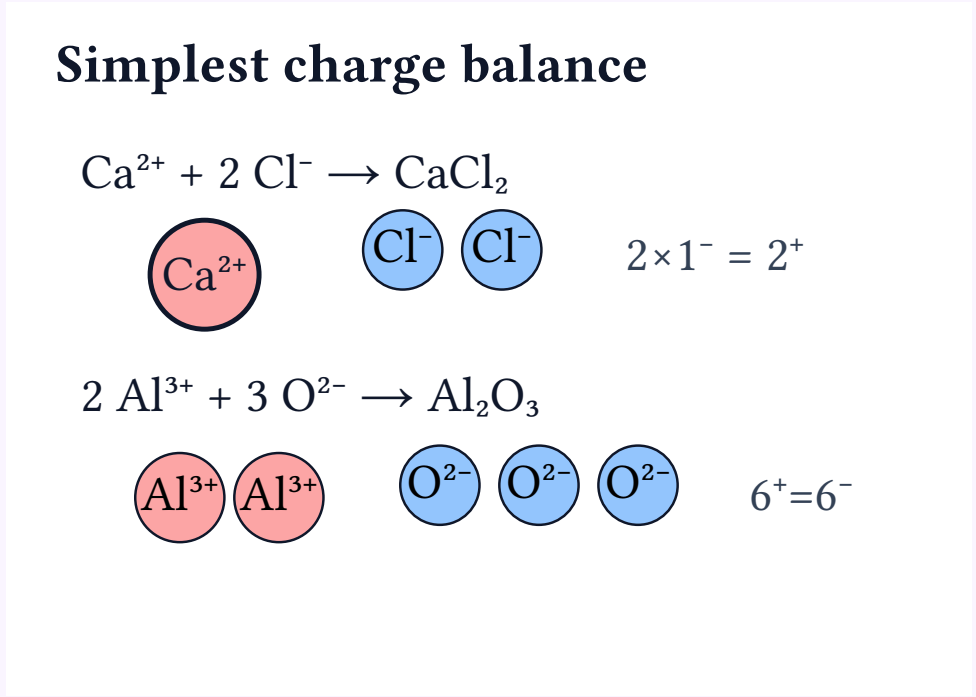
The simplest whole-number ratio of ions that represents an ionic compound. ($CaCl_2$)

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.

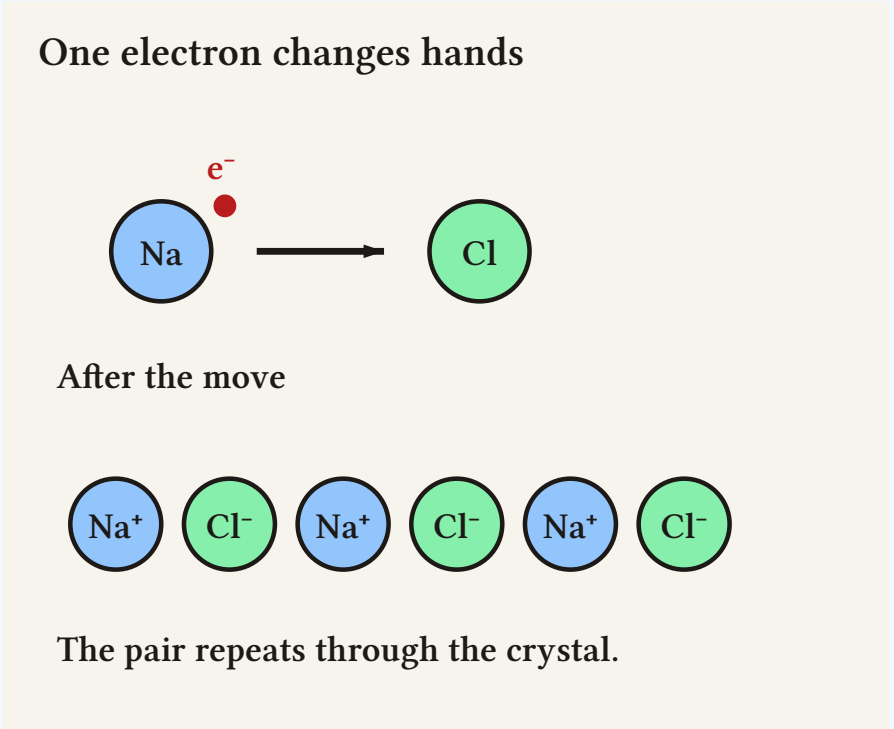
Chemistry 20

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

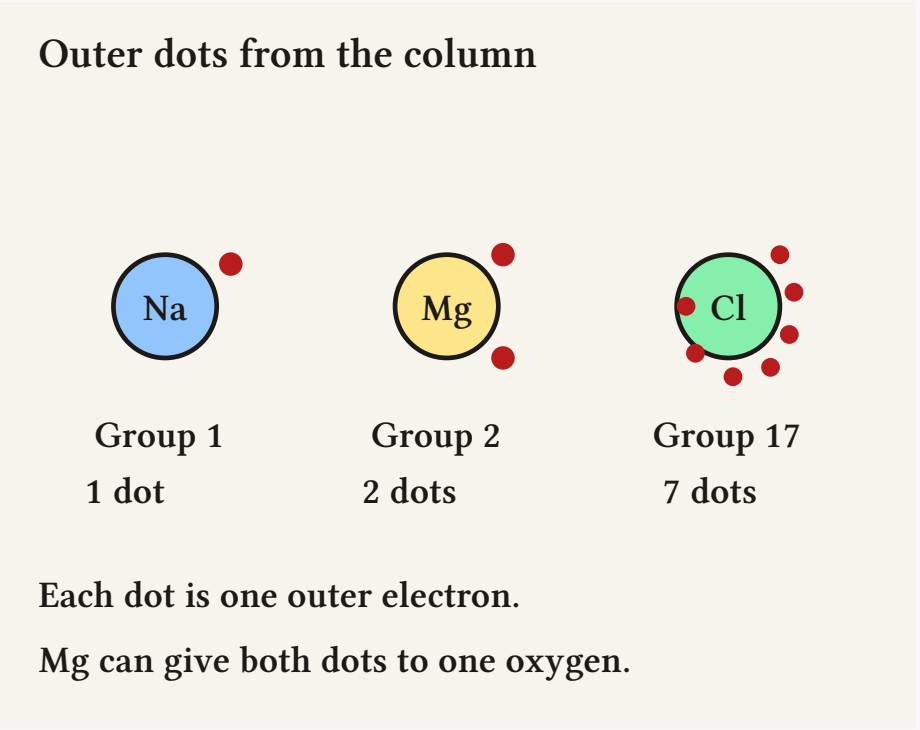
The pull that a positive ion and a negative ion exert on each other at the same time. (Na^+ with Cl^-)

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.

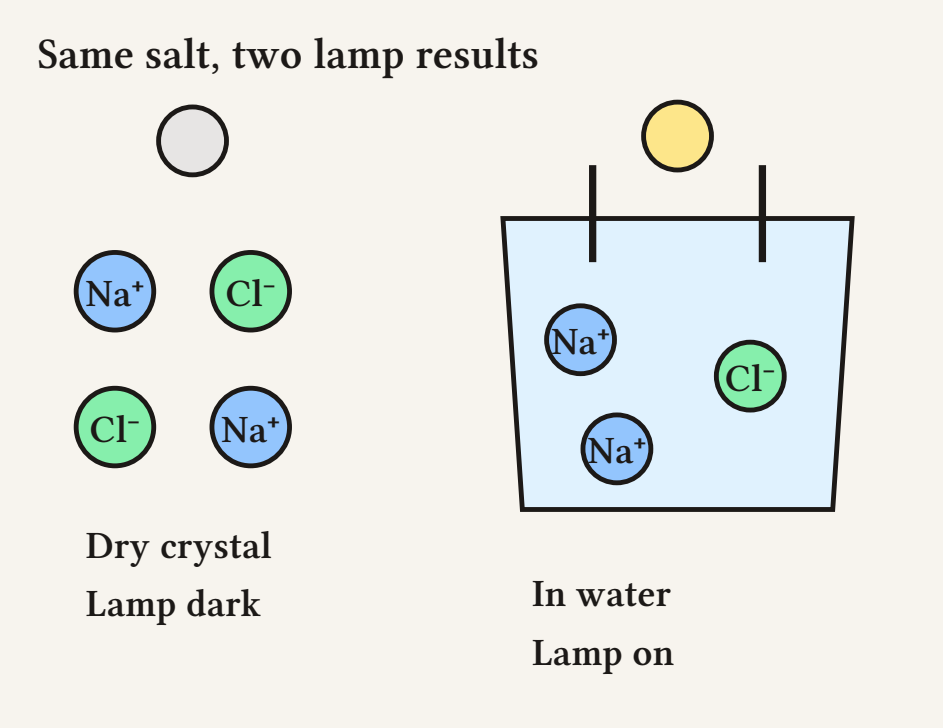
Chemistry 20

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

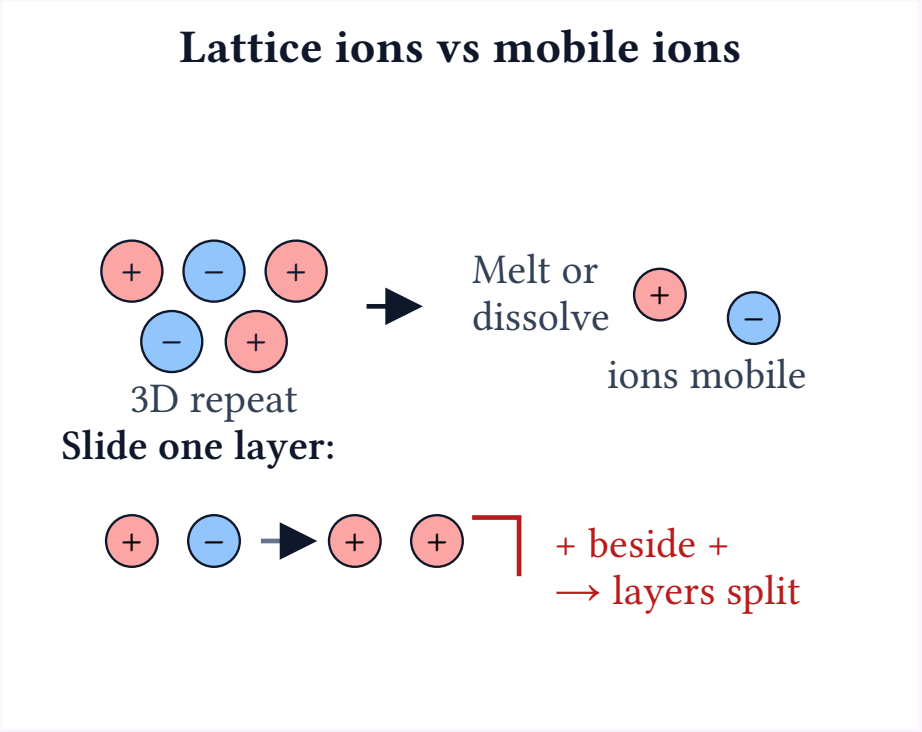
The mass of a solid that dissolves in a stated mass of water at a stated temperature. (36 g in 100 g water)

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.

Chemistry 20

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

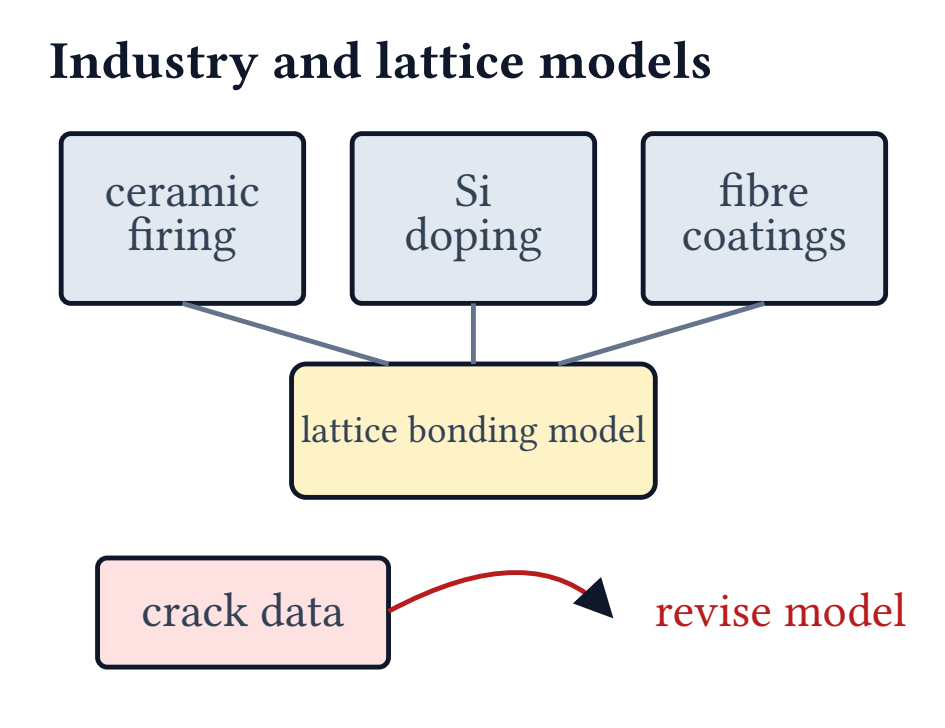
A manufactured solid that combines parts, such as glass fibres in a polymer, so the product has a property neither part has alone. (fibre plus binder)

significant digits

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

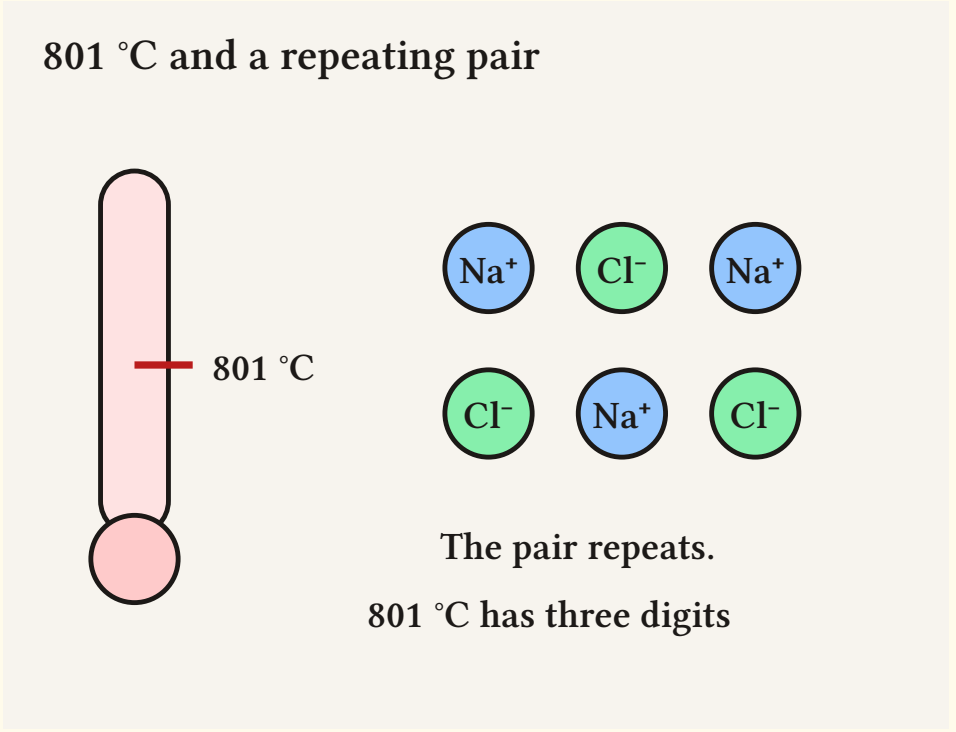
Industry and lattice models

- 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

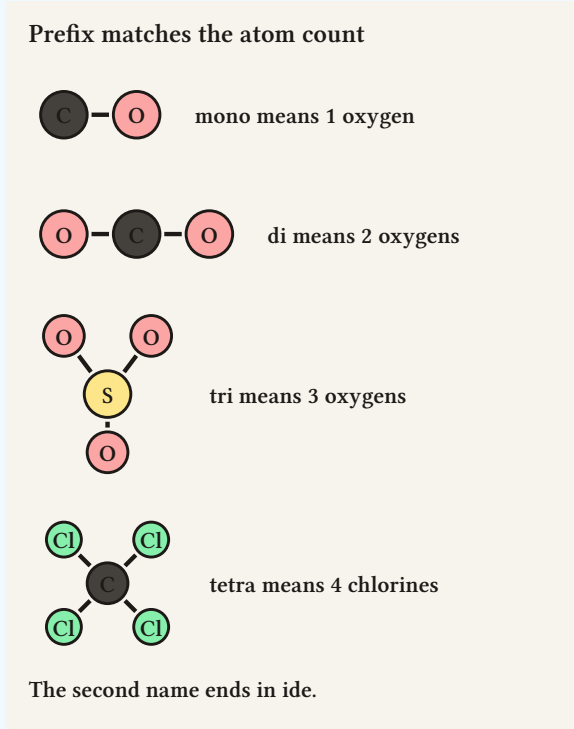
Molecular names and shared pairs

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

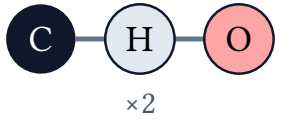
- Each subscript multiplies only the element it follows, unless parentheses say otherwise.
- Glucose, $C_6H_{12}O_6$, keeps its full formula when the molecule itself is meant; CH_2O is only the simplest ratio.

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.

Chemistry 20

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

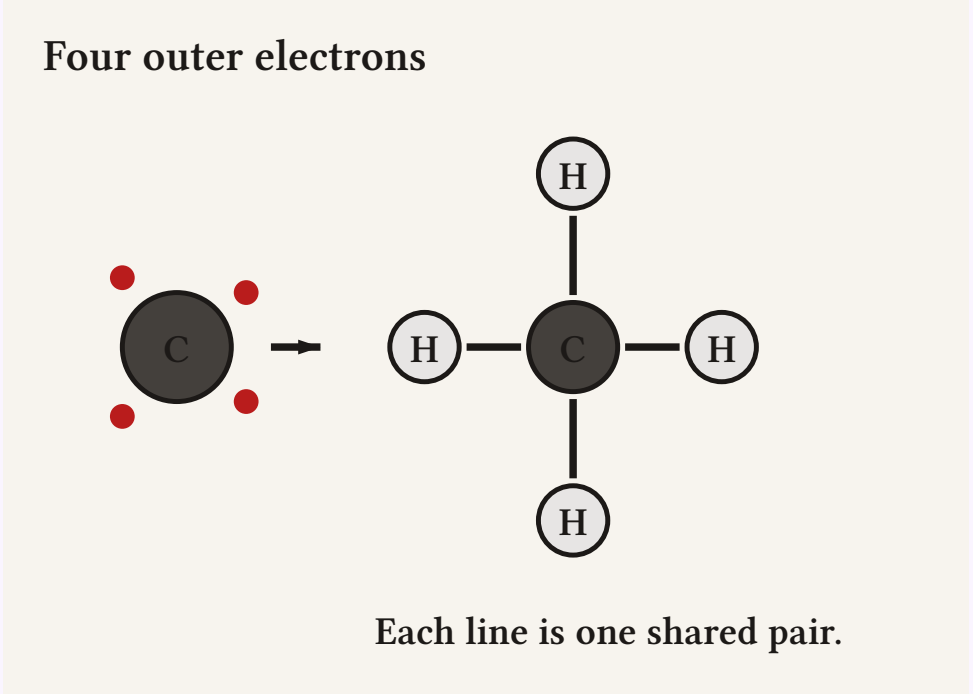
Eight valence electrons around C, N, O, or F in the finished drawing. (8 electrons)

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

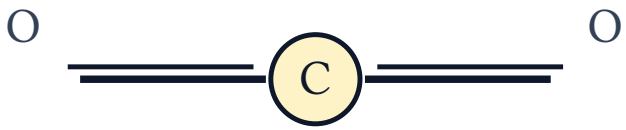
The pull along one bond when the two atoms share electrons unequally. (partial charges)

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

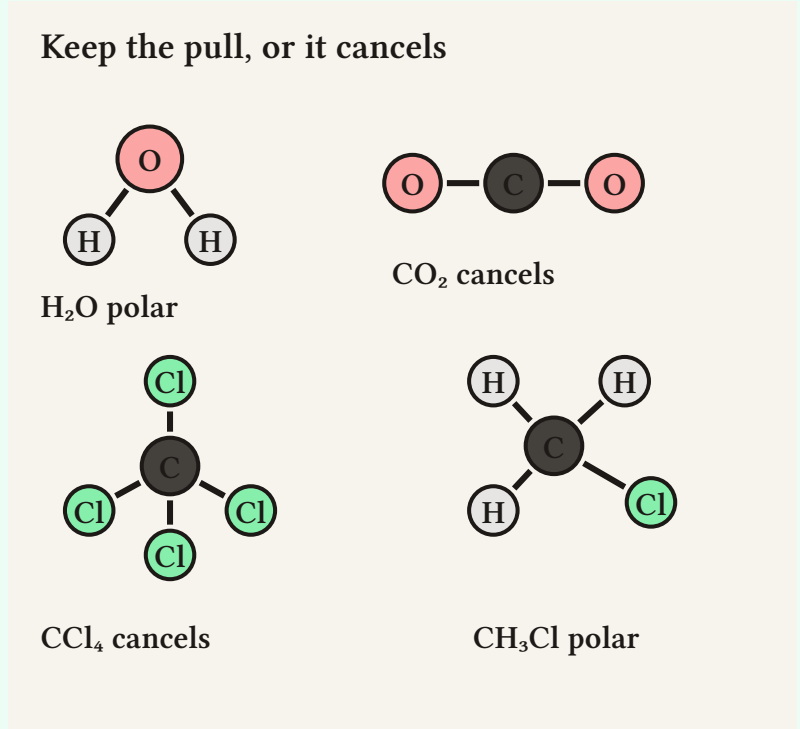
- CO_2 is linear, CH_4 is tetrahedral, and BF_3 is trigonal planar.
- NH_3 is trigonal pyramidal and H_2O is bent.

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.



Chemistry 20

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

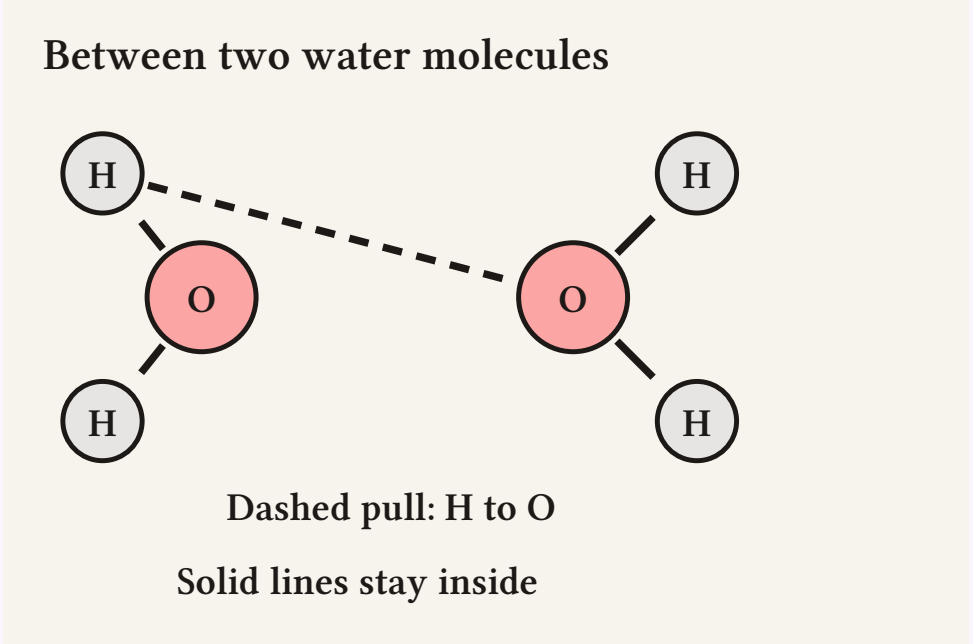
The attraction from a hydrogen attached to N, O, or F toward a lone pair on N, O, or F in a neighbouring molecule. (H with N, O, or F)

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.

Chemistry 20

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

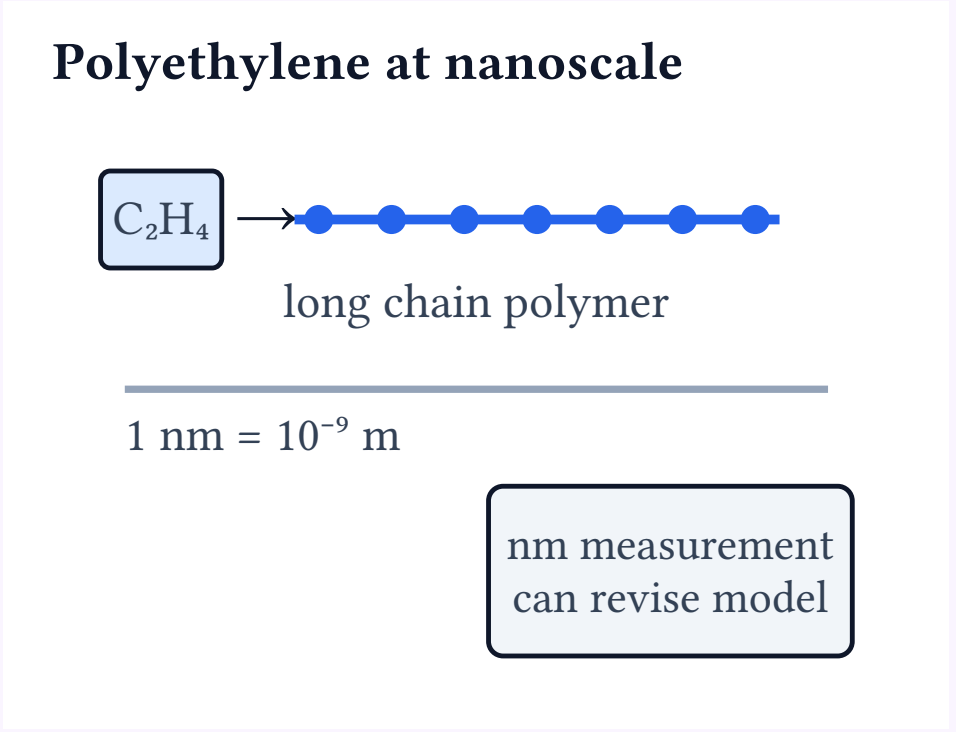
Work at the scale of a nanometre, one billionth of a metre, where new measurements can revise a model of how atoms are arranged. (10^{-9} m)

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.

Image credits

Nachovfranco, Sucrose crystals, CC BY-SA 4.0

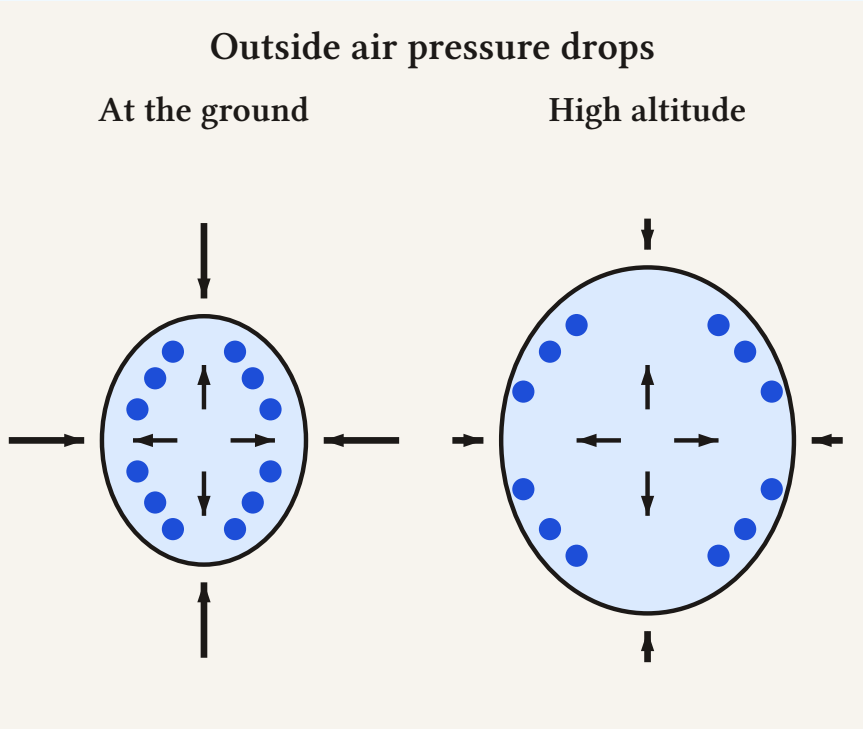
Chemistry 20

Unit B: Gases and the gas laws

Real gases and the ideal gas model

One balloon, two altitudes

- The balloon grows because the outside air pressure drops, while the gas inside keeps pushing out.
- Outside arrows point in, long at the ground and short at altitude. Inside arrows point out and stay the same length.



Three rules build the ideal picture

- An ideal gas uses negligible particle volume, elastic collisions, and no attractive forces.
- A real gas keeps the same moving particles, and its volume and attractions show up at high pressure and low temperature.

Key terms

kinetic molecular theory

A model that explains gas pressure and temperature through the motion and collisions of tiny particles. (KMT)

ideal gas

A gas model in which particle volume is negligible, collisions are elastic, and particles have no attractive forces.

real gas

A gas whose particle volume and attractive forces change the measurements at high pressure or low temperature.

Altitude keeps helium near the ideal picture

- Helium in the weather balloon is far above its condensation temperature, and the pressure on its skin is low.
- The larger volume in thin air follows from a lower outside pressure acting on the same moving particles.



Balloon and cold cylinder

- Helium at ordinary weather-balloon pressures matches the ideal gas rules.
- Carbon dioxide that is cold and highly compressed needs the real-gas corrections.

Nitrogen in two conditions

- Nitrogen in open room air is warm relative to its boiling point and is only lightly compressed.
- Nitrogen squeezed and cooled toward the liquid needs the real-gas picture.

Which picture fits

- Explain the weather balloon at low altitude and in thin air with one ideal-gas story.
- Name the conditions that make particle volume and attractions matter for a real gas.

Image credits

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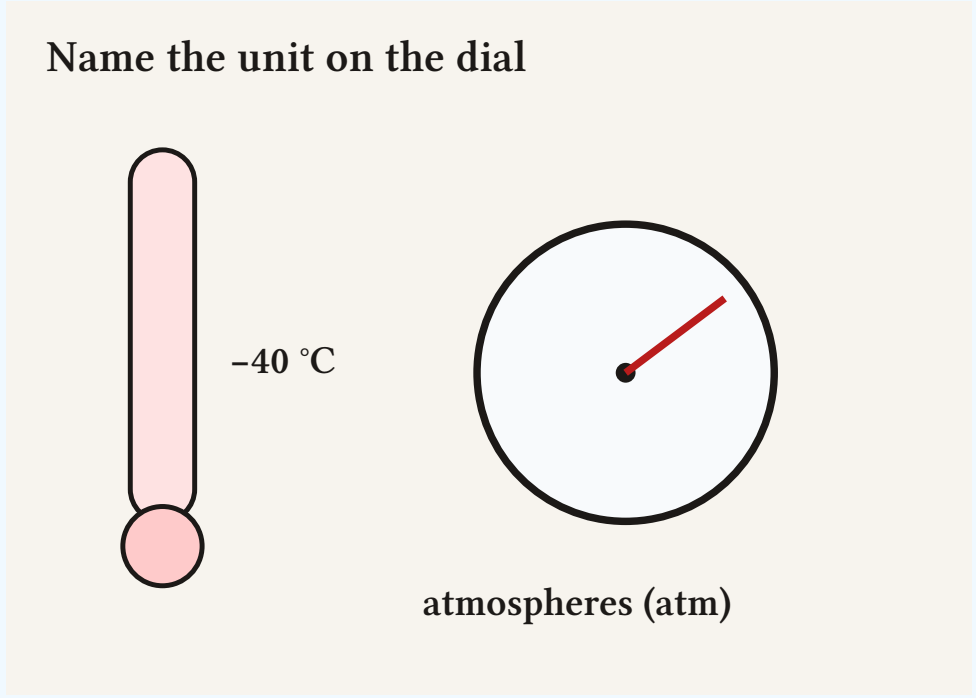
Chemistry 20

Unit B: Gases and the gas laws

Kelvin temperature and pressure units

A cold morning and two dials

- A bench thermometer can read −40 °C while a nearby gauge is marked in atmospheres.
- Gas calculations need one temperature scale and a stated pressure unit before any proportion is written.



Kelvin and pressure units

- Kelvin temperature equals the Celsius reading plus 273.15, and absolute zero is 0 K.
- Sea-level air pressure can be written 101.325 kPa, 1 atm, or 760 mmHg, and precise instruments made those readings trustworthy.

Key terms

kelvin

The temperature scale that places its zero at absolute zero and is reached from Celsius by adding 273.15. (K)

absolute zero

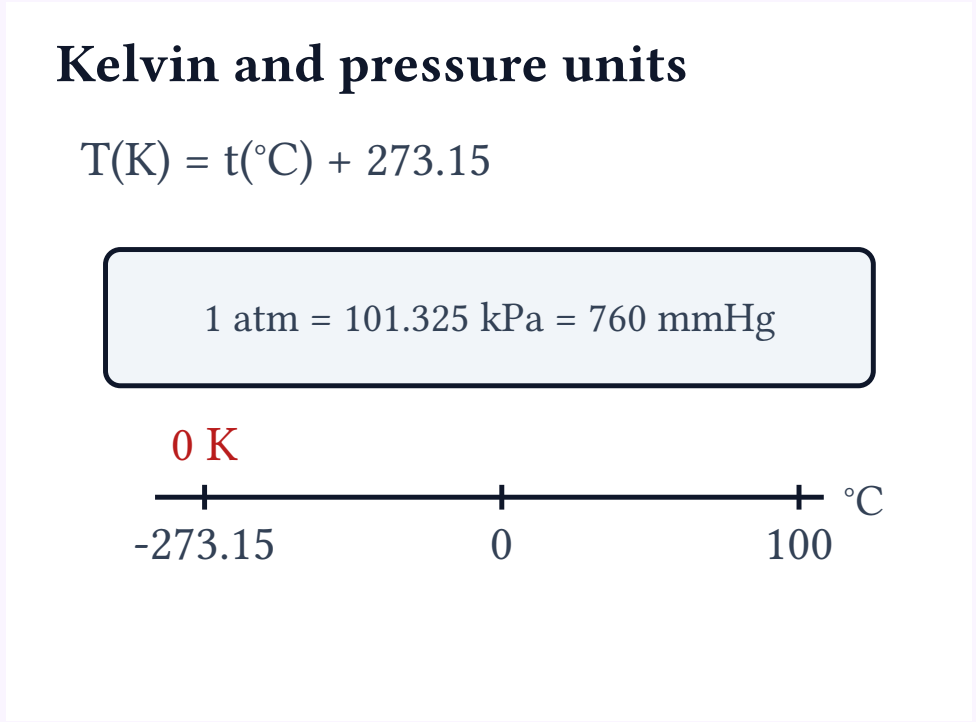
The zero point on the kelvin scale, written 0 K, equal to −273.15 degrees Celsius. (0 K)

kilopascal

A pressure unit in which average sea-level air pressure is 101.325, the same pressure as 1 atmosphere or 760 millimetres of mercury. (kPa)

Absolute zero and pressure units

- T(K) = t(C) + 273.15, so 0 K equals −273.15 °C.
- That same pressure is 101.325 kPa, 1 atm, and 760 mmHg.



Three temperature conversions

- Each Celsius reading increases by 273.15 on the way to kelvin.
- For a negative Celsius reading, you still add 273.15.

Converting 2.00 atm both ways

- Use 101.325 kPa for each atmosphere when the target unit is kilopascals.
- Use 760 mmHg for each atmosphere when the target unit is millimetres of mercury.

Temperature and pressure

- Convert 100 °C to kelvin and state the Celsius mark of absolute zero.
- Say what a thermocouple, a thermistor, and a Bourdon gauge measure.

Chemistry 20

Unit B: Gases and the gas laws

The gas laws

Syringe compression and heating

- Pushing a sealed syringe in at one temperature makes the trapped air push back harder.
- Warming that same air while the plunger is free to move makes the volume grow instead.

Three equations, each with a fixed quantity

- Boyle’s law is P1V1 = P2V2 when temperature and amount stay constant.
- Charles’s law is $V_1/T_1 = V_2/T_2$ in kelvin, and the combined law is $P1V1/T_1 = P2V2/T_2$.

Key terms

Boyle's law

At constant temperature and amount of gas, the product of pressure and volume stays the same. (P1V1 = P2V2)

Charles's law

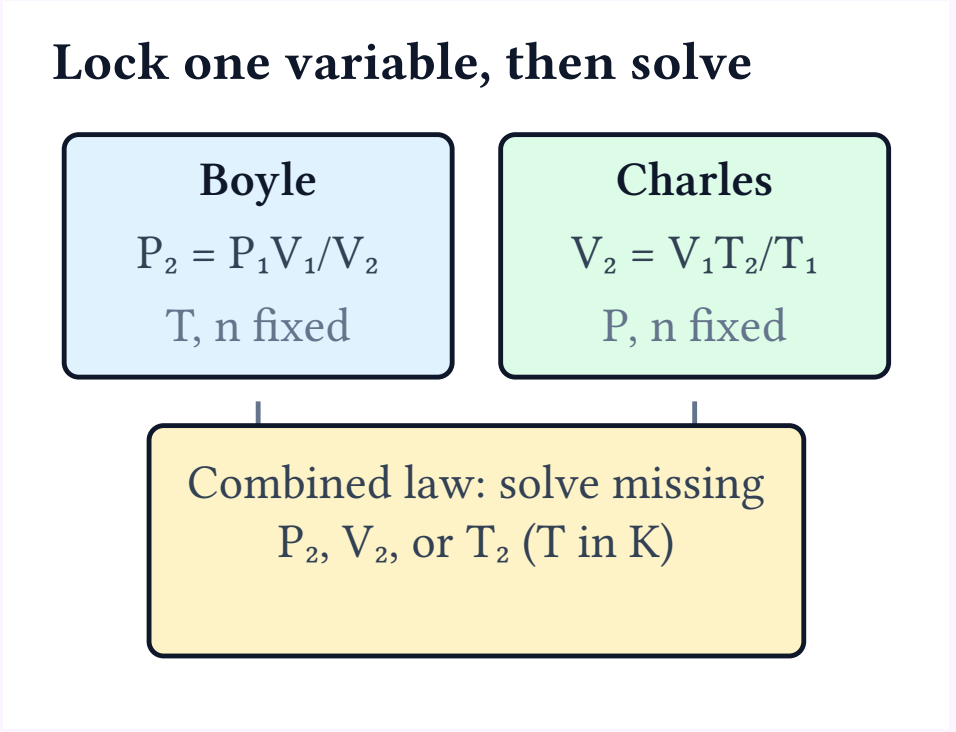
At constant pressure and amount of gas, volume divided by kelvin temperature stays the same. ($V_1/T_1 = V_2/T_2$)

combined gas law

For a fixed amount of gas, $P1V1/T_1$ equals $P2V2/T_2$ when pressure and temperature both change. ($P1V1/T_1 = P2V2/T_2$)

Lock one variable, then solve

- Boyle's law solves $P_2 = P1V1/V_2$, and Charles's law solves $V_2 = V1T2/T_1$.
- The combined law solves whichever of P_2, V_2, or T_2 is missing, with T in kelvin.



Compress 2.40 L at 100 kPa to 0.800 L

- Temperature and amount stay constant, so Boyle’s law applies.
- The new pressure is the original pressure scaled by 2.40/0.800.

Heat 1.50 L from 300 K to 450 K

- Pressure and amount stay constant, so Charles’s law applies.
- Both temperatures are already kelvin, so no 273.15 shift is still waiting.

Pressure and temperature both change

- A fixed amount of gas starts at 100 kPa, 3.00 L, and 300 K.
- Find the volume at 200 kPa and 400 K with the combined law.

Chemistry 20

Unit B: Gases and the gas laws

Calculations with the ideal gas law

Four measurements, one equation

- A sealed sample has a pressure, a volume, a temperature, and an amount of gas, and any three determine the fourth.
- The link among those four is the ideal gas law, once the temperature is in kelvin and the units match R.

PV = nRT and molar volumes

- Rearrange PV = nRT to isolate the measurement the problem asks for.
- At STP one mole occupies 22.4 L, and at SATP one mole occupies 24.8 L.

Key terms

ideal gas law

The equation PV = nRT connecting pressure, volume, amount of gas, and kelvin temperature. (PV = nRT)

molar volume

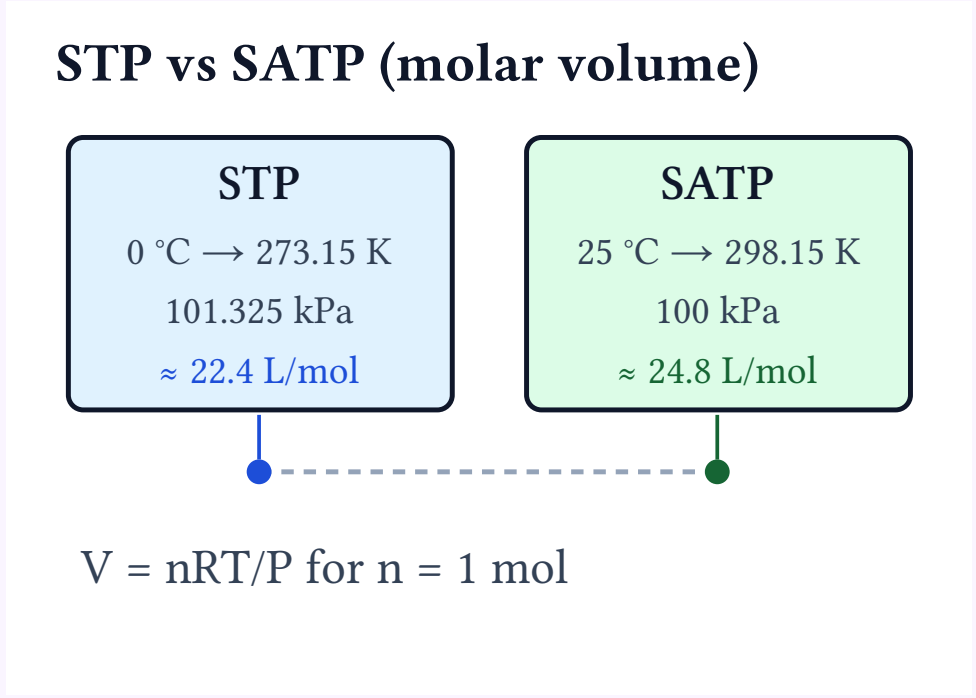
The volume of one mole of gas at a stated temperature and pressure, 22.4 $L \cdot mol^{-1}$ at STP and 24.8 $L \cdot mol^{-1}$ at SATP. ($L \cdot mol^{-1}$)

gas constant

The constant R in PV = nRT, equal to 8.314 when pressure is in kilopascals, volume in litres, amount in moles, and temperature in kelvin. (R)

Where 22.4 and 24.8 come from

- STP is 0 °C, which is 273.15 K, and 101.325 kPa.
- SATP is 25 °C, which is 298.15 K, and 100 kPa.



Pressure of 0.250 mol in 5.00 L

- The sample is 0.250 mol in 5.00 L at 298.15 K.
- Pressure is nRT/V, and the result rounds to 124 kPa.

Amount in 11.2 L at STP

- STP supplies the molar volume 22.4 $L \cdot mol^{-1}$.
- The same amount should appear from PV/RT within ordinary rounding.

SATP volume and the right conditions

- Find the volume of 0.200 mol at SATP using 24.8 $\mathrm{L \cdot mol^{-1}}$.
- Say what volume you would wrongly get if you used 22.4 $\mathrm{L \cdot mol^{-1}}$ instead.

Chemistry 20

Unit B: Gases and the gas laws

Combining volumes and gas technologies

Hydrogen and oxygen volume ratio

- When hydrogen gas and oxygen gas form water vapour at one temperature and one pressure, their volumes follow the coefficients.
- The reaction $2\,H_2 + O_2 \longrightarrow 2\,H_2O(g)$ therefore uses volumes in the ratio 2:1:2.

Volume ratios in devices

- Multiply a known gas volume by a coefficient ratio to find the other gas volumes at the same temperature and pressure.
- Breathing, diffusion, weather, balloons, tanks, air bags, turbines, and engines each show a gas property in use.

Key terms

law of combining volumes

At the same temperature and pressure, the volumes of gases in a reaction are in the same ratio as their coefficients. (2:1:2)

density

Mass divided by volume. Heated air in an open balloon has a lower density than the cooler air outside. (g/L)

diffusion

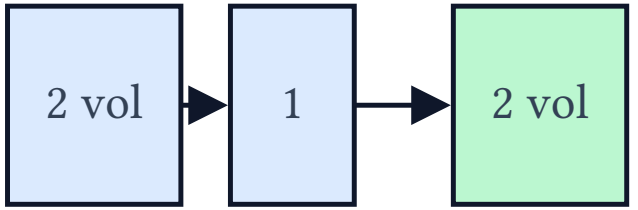
The net spread of gas particles from a region of higher concentration toward a region of lower concentration.

Coefficients are the volume recipe for gases

- The law of combining volumes applies only to substances that are gases at the shared temperature and pressure.
- A coefficient of 2 means twice the volume of a coefficient of 1.

Coefficients = gas volumes

$2\ H_2(g) + O_2(g) \longrightarrow 2\ H_2O(g)$



Same T and P; gases only
Coeff 2 = twice volume of 1

Volumes for 6.00 L of hydrogen

- Hydrogen's coefficient is 2, oxygen's coefficient is 1, and water vapour's coefficient is 2.
- The gases react completely at one temperature and one pressure.

Scaling ammonia from 9.00 L of hydrogen

- The equation $N_2 + 3\ H_2 \longrightarrow 2\ NH_3$ uses gas volumes in the ratio 1:3:2.
- Hydrogen is the known volume, 9.00 L, at the same temperature and pressure as the other gases.

Gases in devices

- Explain a hot-air balloon, an air bag, and a scuba tank with three different gas properties.
- Keep the balloon answer on density and the air-bag answer on a reaction that produces gas.

Chemistry 20

Unit B: Gases and the gas laws

Investigations of gas behaviour

A falling gauge and a capped syringe

- People connected with the land, including Indigenous communities and agricultural workers, have read plant and animal responses as signs of changing atmospheric pressure.
- A capped syringe on the same bench asks a different question: which quantities you will hold still while you change one other.

Safety first, then a fair table

- Read the WHMIS label and the safety data sheet before a gas cylinder is opened or a reaction that makes a gas is started.
- The investigation names controlled variables, graphs the data, identifies a gas or finds R, and keeps every trial.

Key terms

controlled variable

A quantity kept unchanged so the test shows the effect of the one quantity that is deliberately varied.

molar mass

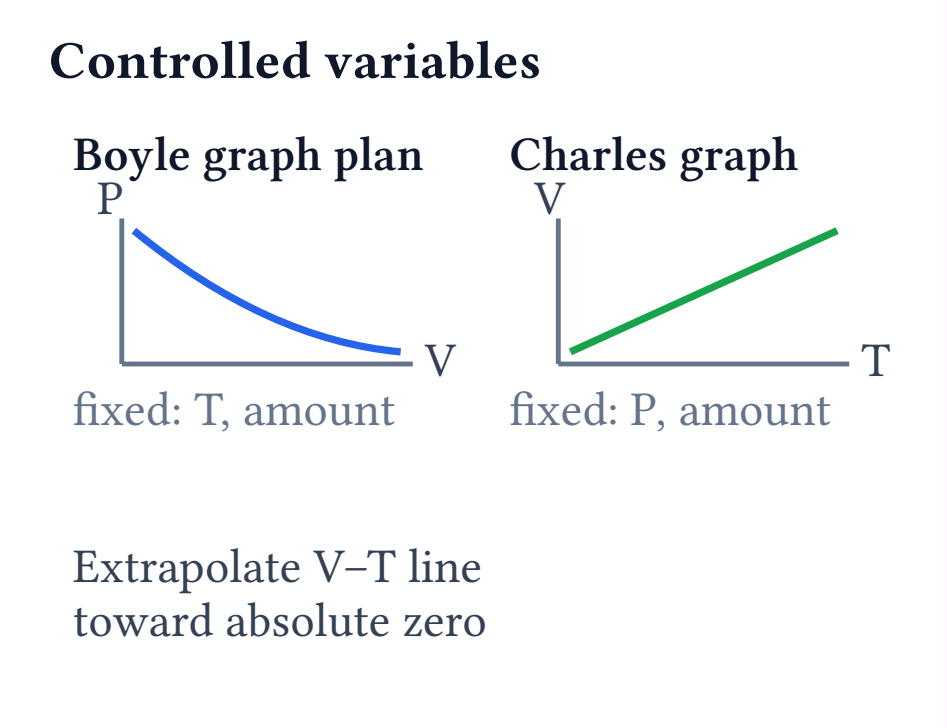
The mass of one mole of a substance. For an unknown gas it is calculated from $M = mRT/PV$. ($g \cdot mol^{-1}$)

WHMIS

The Workplace Hazardous Materials Information System of labels and safety data sheets used before hazardous products are handled.

Controlled variables and graphs

- A Boyle plan keeps temperature and amount fixed while pressure and volume change.
- A Charles plan, or an absolute-zero graph, keeps pressure and amount fixed while volume and temperature change.



Gas identity from M = mRT/PV

- A 2.200 g sample occupies 1.120 L at 101.325 kPa and 273.15 K.
- The molar mass is compared with carbon dioxide, 44.01 g·mol⁻¹.

A constant product and a temperature window

- Three Boyle pairs can be tested by multiplying pressure by volume.
- The thermometer limit belongs in the same report as the graph.

R from the whole table

- A group presentation shows how pressure, volume, temperature, and amount determine R.
- Every trial remains in the shared table while groups compare values.

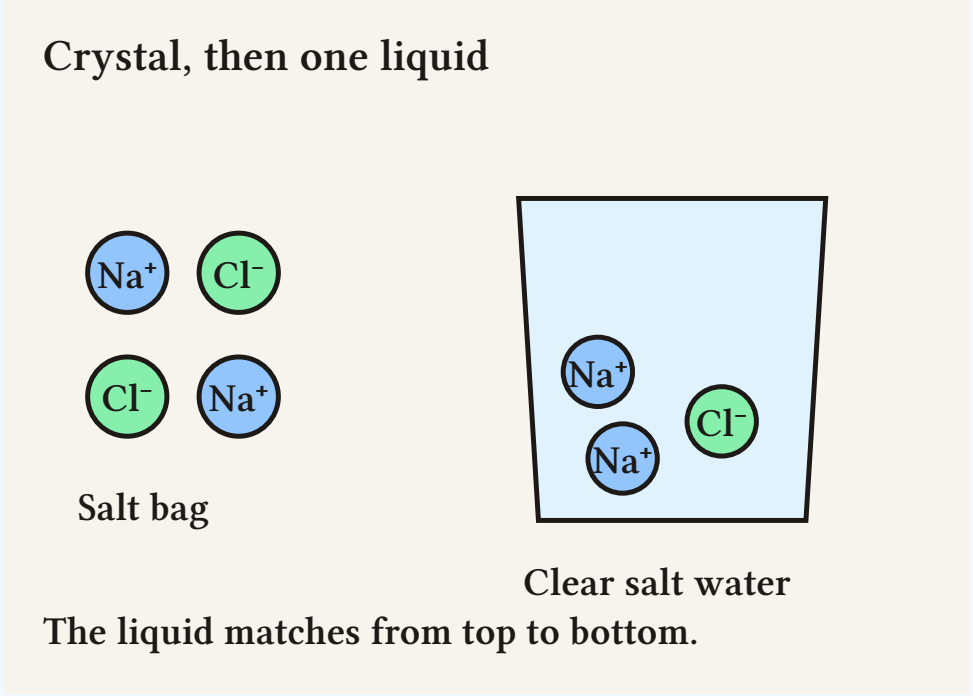
Chemistry 20

Unit C: Solutions and acid-base chemistry

Homogeneous mixtures and dissolving

Solutions and mixtures

- A sealed bag of road salt holds the pure substance sodium chloride, and every crystal has the same ion ratio.
- Salt stirred into water until the solid disappears leaves one clear liquid with matching composition from top to bottom.



Uniform mixing comes before many changes

- Pure substances are elements or compounds, and mixtures are either uniform solutions or samples with visible parts.
- Dissolved ions or molecules can collide, which is why dissolving in water often comes before a chemical change.

Key terms

pure substance

Matter made of one element or one compound, with a fixed composition. (NaCl)

solution

A homogeneous mixture with one visible phase and the same composition in every portion. (salt water)

solute

The substance whose particles spread through the solvent when a solution forms. (NaCl)

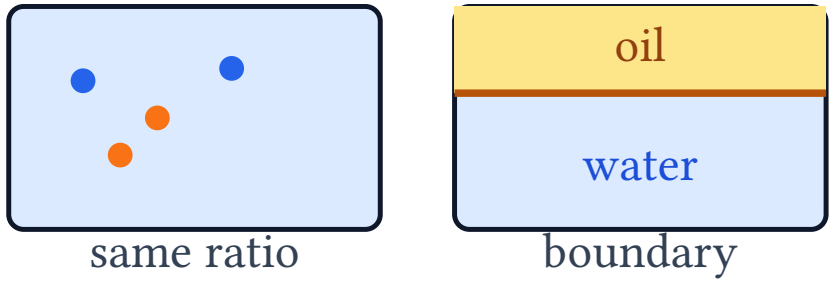
solvent

The substance that does the dissolving and is usually present in the greater amount. (water)

One phase means one particle ratio

- Solute particles spread among solvent particles until every small region has the same ratio.
- Oil over water, or sand under clearer water, keeps a boundary and more than one phase.

One phase vs boundaries



Dissolving spreads solute until uniform

Why the cold pack feels cold

- Pulling solute particles apart and pulling solvent particles apart both absorb energy.
- Attractions that form between solute and solvent release energy, and the larger total sets the temperature change.

Completing the warm-pack tally

- A calcium chloride warm pack warms the skin when the new attractions release more energy than separation absorbs.
- The same comparison of two totals decides any dissolving sample once the energies are given.

Phase and energy sign

- Classify filtered copper sulfate solution and orange juice with pulp by the number of phases.
- Use 55 kJ absorbed and 30 kJ released to state the net energy and the temperature direction.

Chemistry 20

Unit C: Solutions and acid-base chemistry

Electrolytes and solubility

One lamp on, one lamp dim

- Aqueous sodium chloride closes a conductivity circuit and the lamp glows.
- Aqueous sucrose, table sugar in water, leaves that same lamp dim.

Electrolytes and saturation

- An electrolyte produces mobile ions and the solution conducts. A nonelectrolyte such as sugar stays as whole molecules.
- Solubility is a maximum at a stated temperature, and a saturated solution keeps that maximum by equal rates.

Key terms

electrolyte

A substance that produces mobile ions in solution so the solution conducts electricity. (NaCl(aq))

nonelectrolyte

A substance that dissolves as whole molecules, so the solution conducts poorly. (sucrose(aq))

solubility

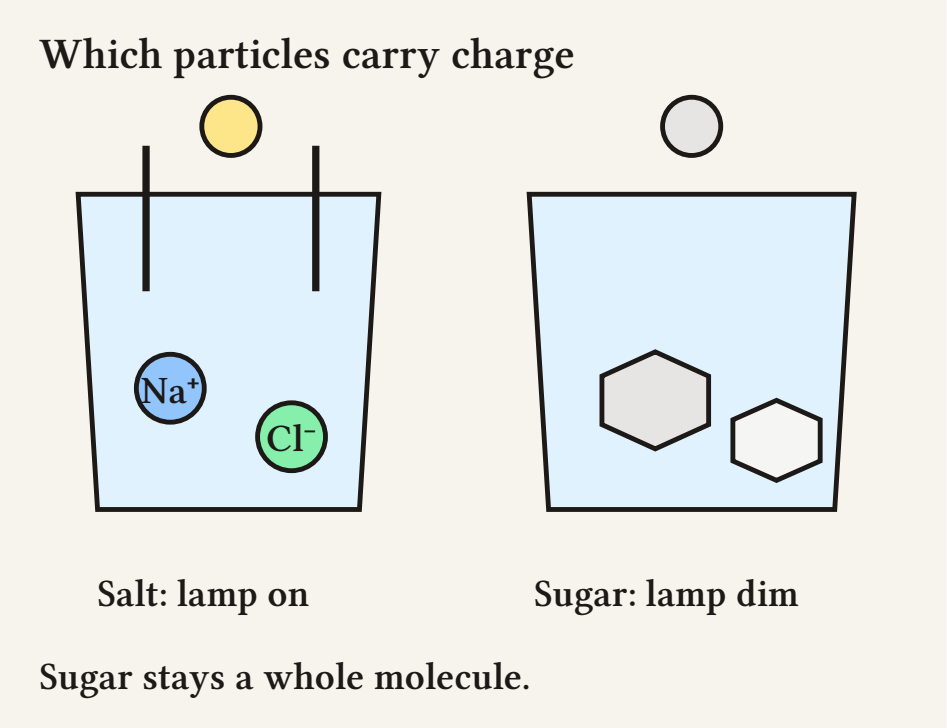
The maximum amount of solute that dissolves in a stated amount of solvent at a stated temperature. (g per 100 g water at 20 °C)

saturated solution

A solution in which dissolving and crystallization continue at equal rates, so the concentration stays steady. (solid still present)

Charge that can travel

- Sodium ions and chloride ions move through water and carry charge to the probes.
- Sucrose molecules spread through water and remain uncharged, so the current stays tiny.



Equal rates, steady dissolved amount

- In a saturated solution, undissolved solid remains in contact with the dissolved solute.
- The dissolving count and the crystallization count match, so the concentration holds steady.

Factors that affect solubility

- Many solids become more soluble in warmer solvent, and gases become less soluble in warmer solvent.
- Gas solubility rises when the gas pressure rises. Ethanol and water mix in all proportions, and oil and water form two layers.

Lamp and limit

- Explain the lamp in aqueous calcium chloride and in aqueous glucose.
- State what equal leave and return rates do to concentration, and what warming does to dissolved oxygen.

Chemistry 20

Unit C: Solutions and acid-base chemistry

Concentration of solutions

Three tags on salty water

- A clinic bag, a lab bottle, and a river report can all describe salty water with different numbers.
- Each number is a ratio, and the ratio is useful only when its unit is named beside it.

Concentration ratios

- $c = n/V$. Here n is moles and V is litres.
- Percent by mass and parts per million, ppm, both compare solute mass with solution mass.
- The unit $mol \cdot L^{-1}$ means moles of solute in one litre of solution.

Key terms

molar concentration

The amount of solute in moles divided by the volume of solution in litres. The unit $mol \cdot L^{-1}$ means moles of solute in one litre of solution. ($c = n/V$)

percent by mass

The mass of solute divided by the mass of solution, multiplied by 100. (% (m/m))

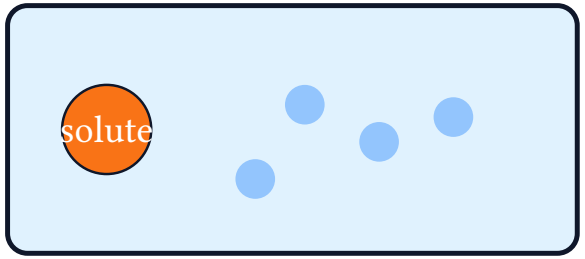
parts per million

The mass of solute divided by the mass of solution, multiplied by one million. The symbol is ppm. (ppm)

The denominator is the whole solution

- Percent by mass divides by the mass of solute plus the mass of solvent.
- A ppm value uses the same solution mass, then scales the ratio by one million.

Denominator = whole solution



mass solute + mass solvent

ppm = same ratio × 10^6

From 2.922 g of salt to mol·L^{-1}

- Convert the measured mass to moles with the molar mass, and convert millilitres to litres.
- Divide the moles by the litres to get c in mol·L^{-1}.

From mol·L^{-1} back to grams

- Multiply c by V, with V in litres, to get the amount of solute in moles.
- Multiply that amount by the molar mass to get the mass to measure.

Concentration units

- Find the percent by mass for 12.0 g of solute dissolved in 108.0 g of water.
- Find c for 1.461 g of NaCl made up to 100.0 mL, and find ppm for 7.5 mg of solute in 1.50 kg of solution.

Chemistry 20

Unit C: Solutions and acid-base chemistry

Dilution and ion concentration

A strong bottle and a milder target

- The stock is 2.00 $mol \cdot L^{-1}$ and the target is 0.200 $mol \cdot L^{-1}$ in 500.0 mL.
- The solute that ends in the flask is a measured portion of that stock, then water fills the flask to the mark.

The amount of solute stays the same

- Symbol c_1 is the stock concentration and V_1 is the stock volume.
- The product of concentration and volume is the amount of solute, and dilution leaves that amount unchanged.
- Symbol c_2 is the diluted concentration and V_2 is the final volume.

Key terms

dilution

Adding solvent so the solution volume rises, the concentration falls, and the amount of solute stays the same. ($c_1 V_1 = c_2 V_2$)

dissociation

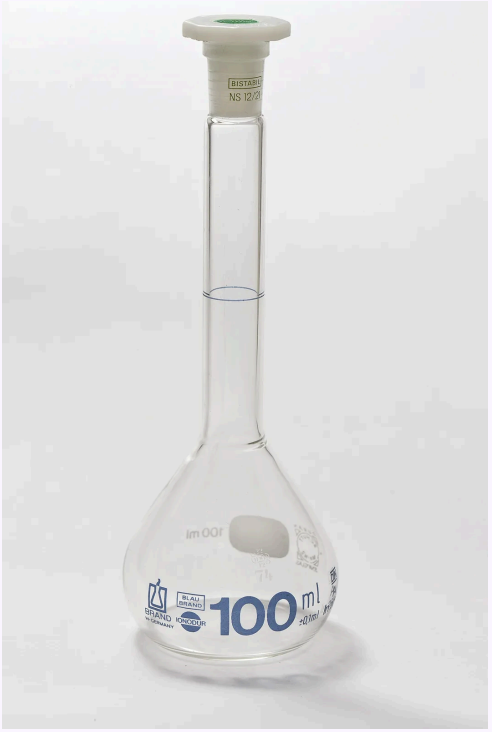
The separation of a dissolved ionic compound into positive ions and negative ions. ($CaCl_2(aq)$)

volumetric flask

A flask with one calibration mark used to hold a stated final volume of solution. (500.0 mL mark)

The volumetric flask mark

- Calculate the mass, dissolve the solid in some water already in the volumetric flask, then fill to the mark.
- Read the label and wear goggles before the solid is transferred.



Diluting 50.0 mL of stock

- Solve $c_1 V_1 = c_2 V_2$ for the stock volume that supplies the solute.
- Add water until the final volume is the flask mark. The volume difference only estimates the water.

Two chloride ions for each formula

- Calcium chloride dissociates as $CaCl_2(aq)$ to $Ca^{2+}(aq)$ plus 2 $Cl^-(aq)$.
- The coefficient of each ion multiplies the compound concentration.

Volume and ions

- Find the stock volume of 3.00 $\text{mol}\cdot\text{L}^{-1}$ solution that prepares 250.0 mL of 0.150 $\text{mol}\cdot\text{L}^{-1}$ solution.
- Find $[\text{Na}^+]$ and $[\text{SO}_4^{2-}]$ in 0.200 $\text{mol}\cdot\text{L}^{-1}$ Na_2SO_4.

Image credits

Lucasbosch, Brand volumetric flask 100ml, CC BY-SA 3.0

Chemistry 20

Unit C: Solutions and acid-base chemistry

Solutions in society and the laboratory

Solutions in daily life

- Sports drinks, intravenous saline, and river samples are all solutions people measure on purpose.
- The number on each container is a concentration chosen for that use.

Three communities, three unit habits

- Laboratories use mol·L^{-1}, households use percent, and environmental studies often use ppm or mg/L.
- Responsible Care members commit to safe handling and to reports the public can read.

Key terms

biomagnification

The rise in concentration of a stored substance along a food chain, so predators hold more than the water did. (methylmercury)

Responsible Care

The Chemistry Industry Association of Canada program, begun under the Canadian Chemical Producers' Association, in which member companies commit to safe handling and public reporting. (public reports)

stewardship

A commitment to meet a human need while keeping the environment able to recover, shown here by a smaller release and a downstream check. (effluent plan)

effluent

Wastewater released from a process into a waterway. (plant outflow)

Key terms

WHMIS

The Workplace Hazardous Materials Information System, which uses labels and pictograms to communicate hazards before a product is handled. (pictogram)

Stored substances climb the food chain

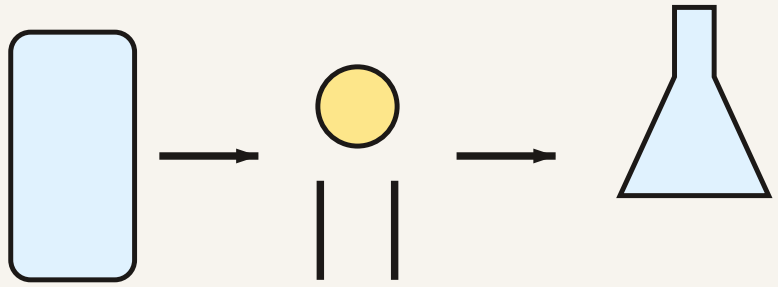
- Biomagnification turns a tiny concentration in water into a much larger concentration in predators.
- A risk-benefit judgment depends on the concentration and on who is exposed.



A procedure that starts with the label

- Read the WHMIS pictograms and the consumer label, then test conductivity and measure a solid solute.
- Use a balance and a volumetric flask, and compare the calculated concentration with another group.

Label, then the measurement



Bottle label Test probes Volume flask

Compare your result with a partner.

Reducing a release

- Two groups who aimed at the same target compare their calculated concentrations on one graph.
- A stewardship plan names a smaller effluent release and a downstream concentration check.

Unit and commitment

- Match a lab stock, a household cleaner, and a river metal to mol·L⁻¹, percent, and ppm or mg/L.
- State the smaller release and the downstream check in one stewardship plan.

Image credits

Sumeet Moghe, Osprey in flight with a fish kill, CC BY-SA 4.0

Chemistry 20

Unit C: Solutions and acid-base chemistry

Naming and testing acids and bases

Formulas and product labels

- HCl(aq) is hydrochloric acid, H_2SO_4(aq) is sulfuric acid, HNO_3(aq) is nitric acid, and CH_3COOH(aq) is ethanoic acid.
- NaOH(aq) is sodium hydroxide, the base that sits in the same recall set as those four acids.

Names first, then the empirical tests

- Each aqueous formula in the recall set has one IUPAC name, and the (aq) symbol is part of that match.
- Indicator colour, a pH reading, and conductivity are the empirical tests used to sort acidic, neutral, and basic solutions.

Key terms

aqueous acid

An acid whose IUPAC name is used when the formula is marked as dissolved in water. (HCl(aq))

hydronium ion

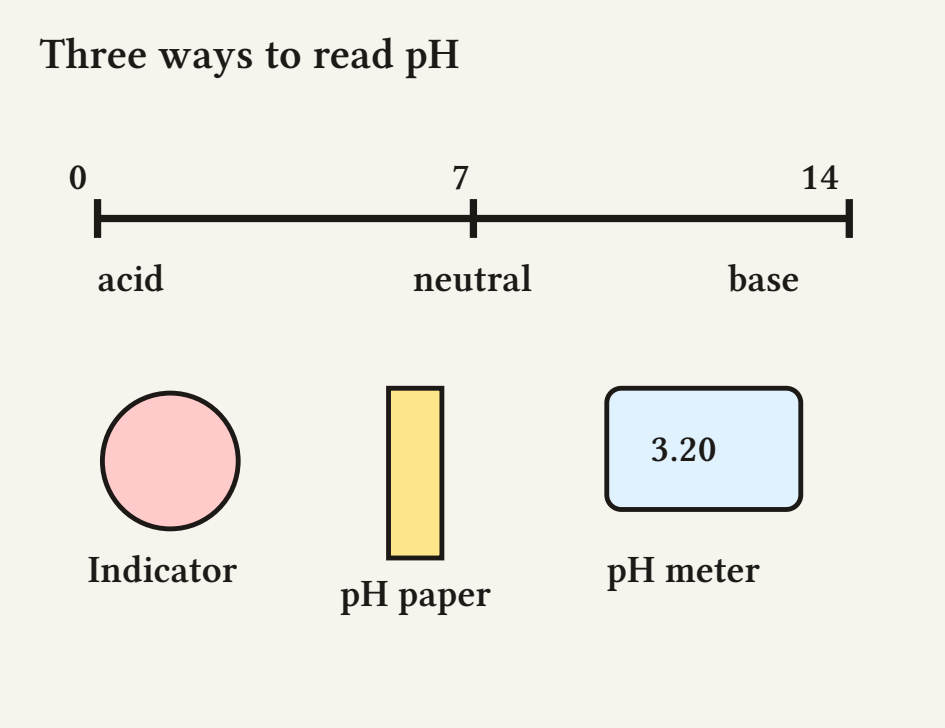
The ion $H_3O^+(aq)$. Square brackets in $[H_3O^+]$ mean its concentration in $mol \cdot L^{-1}$. ($[H_3O^+]$)

pH

The number from $pH = -\log[H_3O^+]$. At 25 °C, values below 7 are acidic, 7 is neutral, and values above 7 are basic. ($pH = -\log[H_3O^+]$)

Indicators and pH meters

- At 25 °C, acidic solutions have pH below 7, neutral solutions have pH 7, and basic solutions have pH above 7.
- An indicator uses a colour match, pH paper uses a paper scale, and a pH meter converts a voltage into pH.

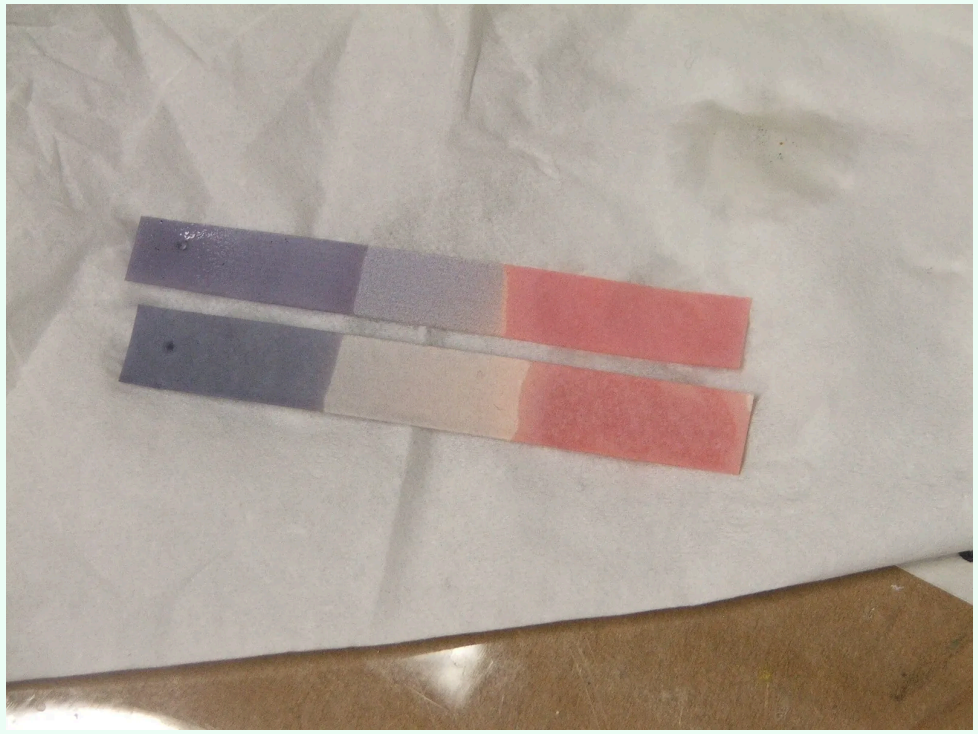


Three observations, one category

- Blue litmus turns red, the display reads pH 3.1, and the conductivity bulb lights.
- The sample is acidic at 25 °C because 3.1 sits below 7.

A cleaner above the neutral mark

- Red litmus turns blue, pH paper matches 10.5, and the solution conducts.
- The number 10.5 is above 7, so at 25 °C the cleaner is basic.



Retrieval of names and a neutral trap

- Give the IUPAC names for $HNO_3(aq)$ and $CH_3COOH(aq)$.
- Classify a conducting sample at pH 7.0 and 25 °C.

Image credits

Chemicalinterest, Litmus paper, public domain

Chemistry 20

Unit C: Solutions and acid-base chemistry

pH and pOH

Significant digits in meter readings

- pH 3.20 comes from a hydronium concentration of 6.3×10^{-4} $mol \cdot L^{-1}$.
- The SI unit on that concentration is $mol \cdot L^{-1}$, moles of solute per litre of solution.



Powers of ten, then the water sum

- A hydronium concentration of 1.0×10^{-3} mol·L^{-1} gives pH 3.00.
- A hydroxide concentration of 1.0×10^{-3} mol·L^{-1} gives pOH 3.00 and pH 11.00 at 25 °C, because pH + pOH = 14.00.

Key terms

hydronium concentration

The amount of H_3O+ in one litre of solution, written $[H_3O+]$ and measured in $mol \cdot L^{-1}$. ($[H_3O+]$)

pOH

The number $-\log[OH^-]$, where $[OH^-]$ is the hydroxide ion concentration in $mol \cdot L^{-1}$. ($pOH = -\log[OH^-]$)

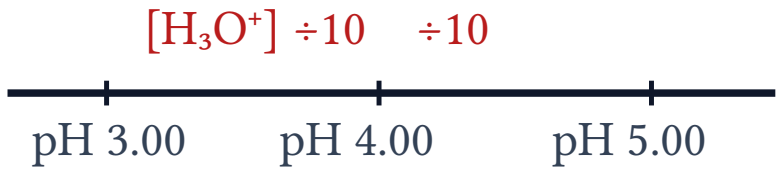
significant digits

The digits in a concentration that are fixed by how many decimal places the pH value shows. (pH 3.20)

Decimal places and a tenfold jump

- The number of decimal places in a pH value equals the significant digits in the concentration.
- A decrease of 1.00 in pH multiplies [H_3O+] by 10, and a decrease of 1.00 in pOH multiplies [OH^-] by 10.

pH decimals and ×10 jumps



2 decimals in pH ⟶ 2 sig figs in [H_3O^+]

Each +1 pH: [H_3O^+] is 10× smaller

From pH 3.20 back to mol·L^{-1}

- pH 3.20 has two decimal places, so the concentration has two significant digits.
- The matching hydronium concentration is 6.3×10^{-4} mol·L^{-1}.

A one-unit drop on the hydroxide scale

- At 25 °C, pOH 3.00 belongs with $[OH^-] = 1.0 \times 10^{-3}$ mol·L^{-1} and with pH 11.00.
- If that pOH decreases by 1.00, the hydroxide concentration is multiplied by 10.

Powers of ten

- Find the pH when $[H_3O^+] = 1.0 \times 10^{-3}\ \text{mol·L}^{-1}$.
- pH 3.20 allows two significant digits in $[H_3O^+]$, reported as $6.3 \times 10^{-4}\ \text{mol·L}^{-1}$.

Image credits

OER CampLev, PH-Meter METTLER TOLEDO FiveEasy, CC BY-SA 4.0

Chemistry 20

Unit C: Solutions and acid-base chemistry

Modified Arrhenius theory and neutralization

Hydrogen chloride meets water

- $HCl(g) + H_2O(l) \longrightarrow H_3O{+}(aq) + Cl^{-}(aq)$ produces the hydronium ion in water.
- A modified Arrhenius acid is defined by that aqueous hydronium, so the definition is limited to water.

Acids and bases in water

- You will write the hydronium equation for hydrogen chloride and state the aqueous limit of the acid definition.
- You will write hydroxide equations for sodium hydroxide and ammonia, then tally neutralization to 2 $H_2O(l)$.

Key terms

modified Arrhenius acid

A substance that produces $H_3O+(aq)$, the hydronium ion, in aqueous solution. ($HCl(g) + H_2O(l)$)

modified Arrhenius base

A substance that produces $OH^-(aq)$, the hydroxide ion, in aqueous solution. ($NH_3(aq)$)

neutralization

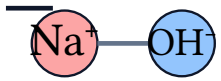
The reaction of hydronium with hydroxide to form water. ($H_3O+(aq) + OH^-(aq) \longrightarrow 2\ H_2O(l)$)

Sources of hydroxide

- $NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$ shows full dissociation of the ionic solid in water.
- $NH_3(aq) + H_2O(l)$ in water makes some $NH_4+(aq)$ and $OH^-(aq)$. The formula NH_3 has no OH group, and only part of the ammonia reacts.

Sources of OH^-

$NaOH(s) \longrightarrow Na^+(aq) + OH^-(aq)$



full dissociation

$NH_3(aq) + H_2O \rightleftharpoons NH_4^+ + OH^-$



NH_3 has no OH group; only part reacts

Hydronium plus hydroxide makes two waters

- Neutralization is $H_3O^+(aq) + OH^-(aq) \longrightarrow 2\ H_2O(l)$.
- The tally is 4 H, 2 O, and charge zero on both sides.

Completing the ammonia equation

- Ammonia in water produces $NH_4^+(aq)$ and $OH^-(aq)$.
- The formula NH_3 contains no hydroxide group, and the modified definition still counts the aqueous hydroxide.

Retrieval of three equations

- Write the modified Arrhenius acid equation for HCl(g) with water.
- Write neutralization as hydronium plus hydroxide, with the coefficient on water.

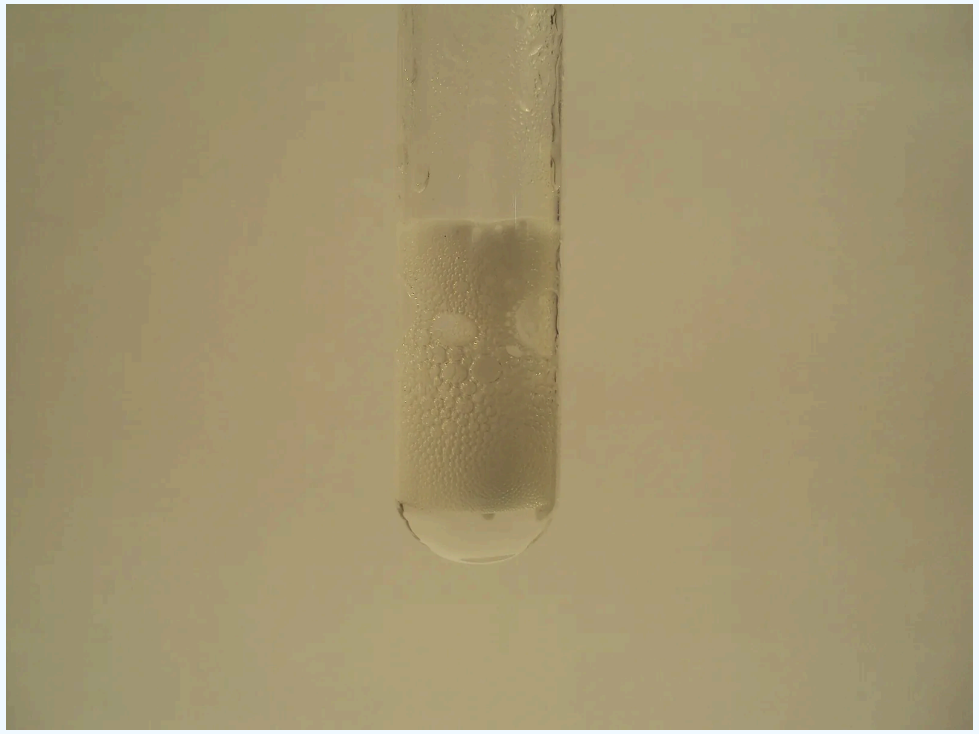
Chemistry 20

Unit C: Solutions and acid-base chemistry

Acid strength and polyprotic acids

Same concentration, different fizz

- At 0.10 mol·L^{-1}, hydrochloric acid ionizes completely and ethanoic acid ionizes only partly.
- The hydrochloric acid sample has the lower pH, the faster reaction with carbonate, and the higher conductivity.



Strength is the fraction ionized

- NaOH dissociates fully, while NH_3 ionizes only partly, so the strong base has more hydroxide and higher conductivity at equal concentration.
- After the strong-weak comparison, you will count how many protons HCl, H_2SO_4, H_3PO_4, NaOH, and carbonate can transfer.

Key terms

strong acid

An acid that ionizes completely in water, so the dissolved amount becomes hydronium and the anion. ($HCl(aq)$)

weak acid

An acid that ionizes only partly in water, so most of the molecules remain intact. ($CH_3COOH(aq)$)

polyprotic acid

An acid that can donate more than one proton, and does so in steps, with the first step more complete. (H_2SO_4)

Monoprotic and polyprotic acids

- Monoprotic HCl donates one proton, and monoprotic NaOH supplies one OH^-.
- Polyprotic H_2SO_4 and H_3PO_4 can donate more than one proton in steps, and CO_3^{2-} can accept more than one.

Mono- vs polyprotic

Monoprotic 

$HCl \longrightarrow H^+ + Cl^-$ (one H^+)

$NaOH \longrightarrow Na^+ + OH^-$ (base, one OH^-)

Polyprotic 

$H_2SO_4 \longrightarrow HSO_4^- \longrightarrow SO_4^{2-}$ (2 steps)

H_3PO_4: up to 3 H^+, one at a time

Polyprotic base: CO_3^{2-} can accept 2 H^+

Sulfuric acid in two steps

- H_2SO_4 donates a proton completely to form HSO_4^-, then HSO_4^- donates a second proton only partly.
- HCl donates one proton and stops, so hydrochloric acid is mono-protic.

Monoprotic and polyprotic bases

- NaOH supplies one OH^-, so it is a monoprotic base.
- CO_3^{2-} can accept more than one proton, so carbonate is a polyprotic base.

Retrieval of strength and proton count

- At 0.10 mol·L^{-1}, compare HCl and ethanoic acid on pH, carbonate rate, and conductivity.
- Classify H_3PO_4 and NaOH as polyprotic or monoprotic.

Image credits

Dr.T, HCl & magnesium, CC BY-SA 3.0

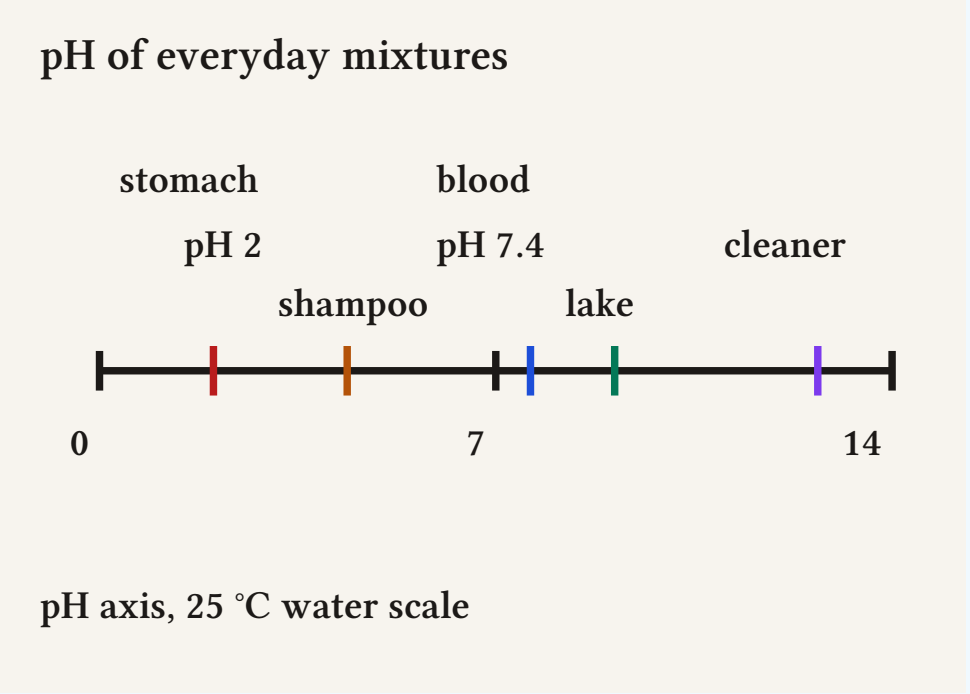
Chemistry 20

Unit C: Solutions and acid-base chemistry

Acids and bases in Alberta

Acids in daily life

- Stomach acid sits near pH 2, blood near 7.4, and many cleaners are basic.
- Pulp and paper, petrochemicals, food preservation, and a car battery all put acid and base chemistry to work.



Strength and concentration

- Solution strength and concentration both matter for pharmaceuticals, spills, transport of dangerous goods, and toxicity.
- You will design indicator, pH, and conductivity tests, graph hydronium against pH, and read WHMIS labels before any container is opened.

Key terms

solution strength

How completely an acid or base forms ions in water, a different fact from how many moles are dissolved per litre. (complete or partial)

acid deposition

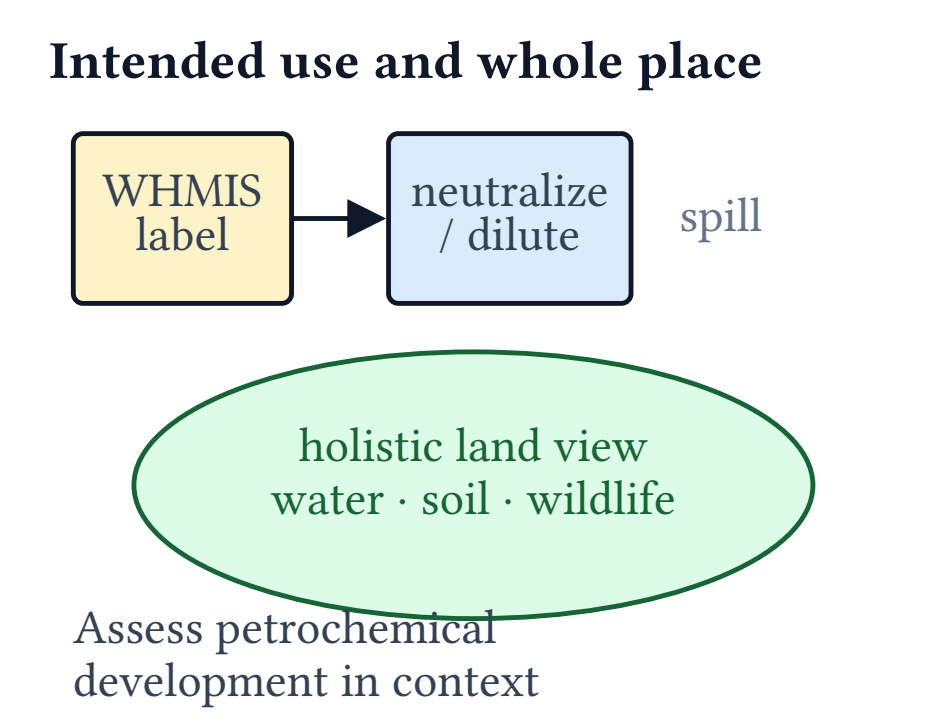
Acid that reaches land and water after gases such as sulfur dioxide and nitrogen oxides form acids in the air. (SO_2 and NOx)

corrosive

The WHMIS and Class 8 dangerous-goods description of many acids and bases that damage tissue and metal. (Class 8)

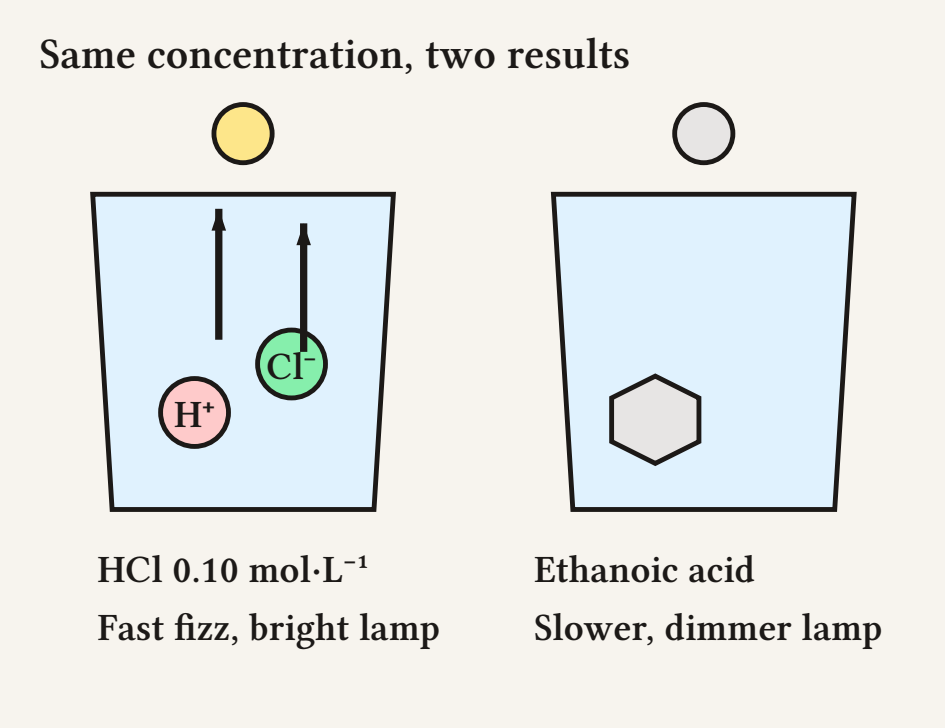
Intended uses and the whole place

- Spill response uses neutralization and dilution only after the label and the WHMIS information are read.
- Some Indigenous communities in Alberta use holistic land practices when they assess petrochemical development.



Design the tests and the falling graph

- Indicator colour and pH separate acidic, basic, and neutral samples after the WHMIS label is read.
- At equal concentration, conductivity and the carbonate rate separate a strong acid from a weak acid.



A corrosive drum and a household pair

- A drum of sulfuric acid is a Class 8 corrosive and needs a WHMIS plan and a dangerous-goods plan.
- Vinegar is acidic ethanoic acid, and a cleaner at pH 12 is basic.

Industry and emissions

- Sulfuric acid links fertilizer, pulp, batteries, and petrochemicals to industrial growth.
- Scrubbers and catalytic converters cut gases that lead to acid deposition, and water treatment, food science, and environmental chemistry are career paths.

Chemistry 20

Unit D: Quantities in chemical change

Reaction types and balanced equations

Names and masses

- A lab page can name the chemicals in a reaction and, on the next line, record how many grams were used.
- The name answers what is present, and the gram record answers how much was measured.

Predicted products

- Five familiar patterns decide the product formulas before any coefficient is chosen.
- After the formulas are fixed, each coefficient is a count of atoms, of molecules, and of moles.

Key terms

formation reaction

A pattern in which separate reactants combine and a single product is formed. (2 Na + Cl_2 ⟶ 2 NaCl)

coefficient

A whole number written in front of a formula to count formula units while the formula stays fixed. (2 H_2)

qualitative analysis

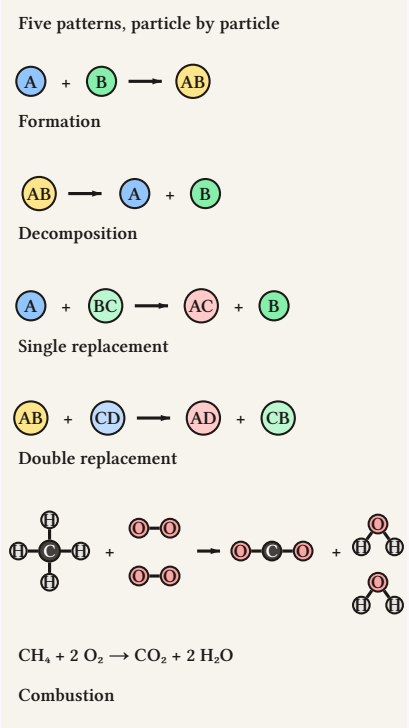
Work that names which substances are present in a sample. (identity)

quantitative analysis

Work that measures how much of a named substance is present. (mass or moles)

Five patterns decide the products

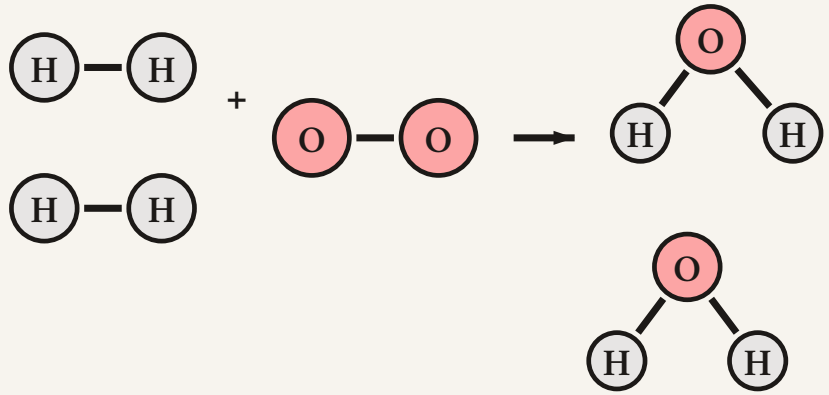
- Formation joins reactants into one product, and decomposition splits one reactant apart.
- Complete combustion of a hydrocarbon in oxygen produces carbon dioxide and water.



One equation, three ways to count

- The balanced hydrogen-oxygen equation uses the same formulas chemists already know from Science 10.
- Each front number is doing counting work for atoms, for molecules, and for moles.

Count atoms, then molecules



$2\ H_2 + O_2 \rightarrow 2\ H_2O$

4 H and 2 O on each side.

Methane combustion

- The skeleton $CH_4 + O_2 \longrightarrow CO_2 + H_2O$ already shows the correct product formulas for complete combustion.
- Lowest whole-number coefficients finish the atom match for carbon, hydrogen, and oxygen.



Patterns and amounts

- A single heated reactant and a hydrocarbon flame are two different product predictions.
- Naming the chemicals is a different job from reporting how many moles the coefficients count.

Image credits

Lisafern, Gas stove burner flame, CC0 1.0

Chemistry 20

Unit D: Quantities in chemical change

Ionic and net ionic equations

A precipitate in solution

- Two clear solutions can mix and produce a white solid while the liquid around that solid stays clear.
- The solid is one new sub-stance, and dissolved ions can remain in the liquid.



Split the solution, then keep the change

- Aqueous strong electrolytes are written as separate ions, and solids stay as complete formulas.
- Ions that match on both sides are set aside so the written change shows the new substance.

Key terms

spectator ion

An ion that stays aqueous and appears unchanged on both sides of an ionic equation. (Na^+ and NO_3^-)

net ionic equation

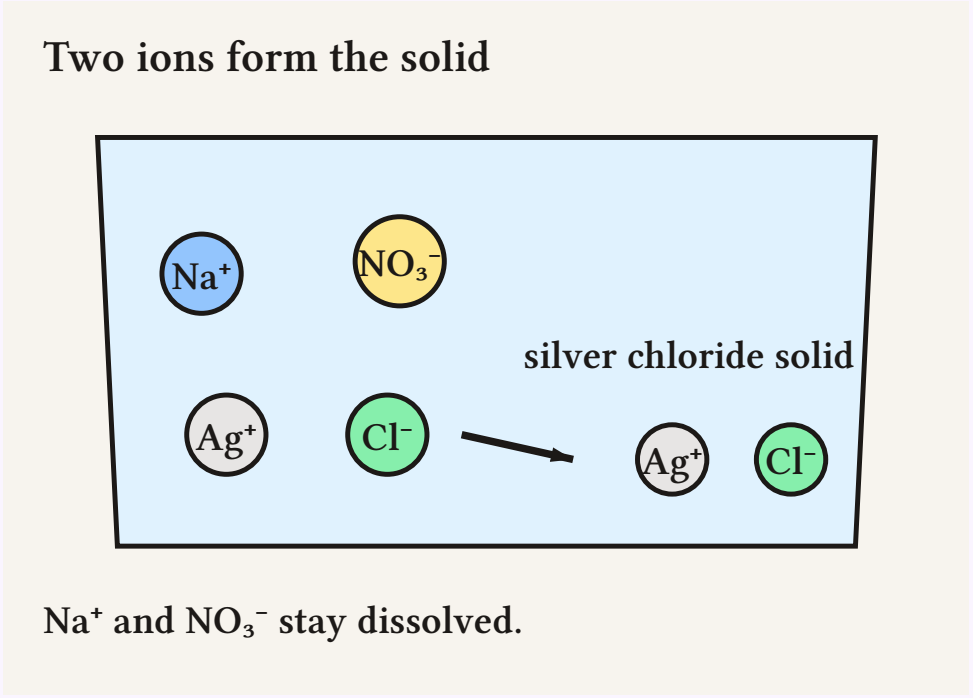
The balanced equation that remains after spectator ions are removed, with state symbols kept. ($Ag^+(aq) + Cl^-(aq) \longrightarrow AgCl(s)$)

full ionic equation

A balanced equation that shows aqueous strong electrolytes as separate ions. ($Ag^+(aq) + Cl^-(aq) + Na^+(aq) + NO_3^-(aq)$)

Sodium and nitrate stay in solution

- The formula equation is $AgNO_3(aq) + NaCl(aq) \longrightarrow AgCl(s) + NaNO_3(aq)$.
- Silver chloride remains a solid formula, and the other three salts are strong electrolytes in water.



Hydronium and hydroxide become water

- The formula equation is $HCl(aq) + NaOH(aq) \longrightarrow NaCl(aq) + H_2O(l)$.
- Water stays a liquid formula, and the aqueous acid, base, and salt can be written as ions.

Carbonate ions meet calcium ions

- The formula equation is $CaCl_2(aq) + Na_2CO_3(aq) \longrightarrow CaCO_3(s) + 2\ NaCl(aq)$.
- Calcium carbonate stays a solid, and the soluble salts are written as ions.

Aqueous changes

- A precipitation and a strong-acid neutralization each leave some ions unchanged.
- The net ionic equation keeps state symbols on the ions and on the new substance.

Image credits

Dr.T, AgCl-neerslag, CC BY-SA 3.0

Chemistry 20

Unit D: Quantities in chemical change

Stoichiometry methods

Stoichiometry equipment

- The same balanced equation can start from grams on a balance, from millilitres in a pipette, or from litres in a gas syringe.
- Each tool measures a different quantity, and the equation still supplies the same kind of ratio.

Three lanes that meet at the mole

- Gravimetric work starts from a mass, solution work starts from a concentration and a volume, and gas work can end at a volume at SATP.
- A plan also names states, products, a theoretical yield, and the WHMIS step that comes first.

Key terms

stoichiometry

The use of a balanced equation to convert the amount of one substance into the amount of another. (mole ratio)

theoretical yield

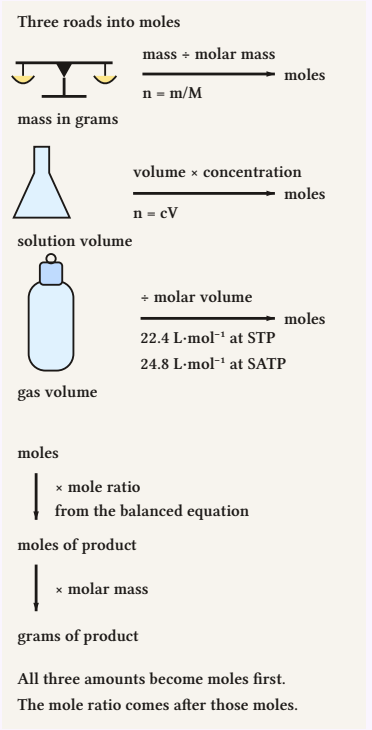
The amount of product calculated from the balanced equation and the starting measurement. (4.40 g CO_2)

molar volume

The volume of one mole of an ideal gas at a stated temperature and pressure. (24.8 $L \cdot mol^{-1}$ at SATP)

The ratio sits between two conversions

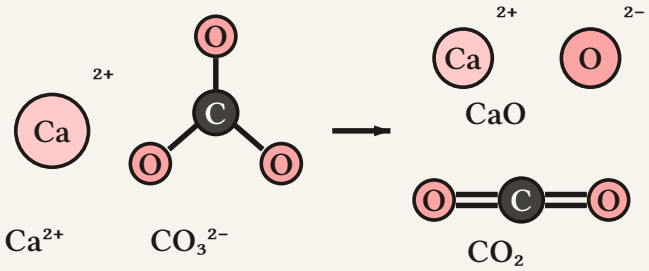
- Divide a mass by the molar mass, or multiply a concentration by the volume in litres, to reach moles.
- The mole ratio from the balanced equation then turns reactant moles into product moles.



Carbon dioxide from 10.0 g of carbonate

- Heating $CaCO_3(s)$ produces $CaO(s)$ and $CO_2(g)$ with a 1 to 1 mole ratio.
- The theoretical yield of carbon dioxide is the mass calculated from 10.0 g of reactant.

$CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$



1 mol $CaCO_3$ gives 1 mol CO_2

$10.0\ g \div 100.09\ g \cdot mol^{-1}$
$= 0.0999\ mol$

$0.0999\ mol \times 44.01\ g \cdot mol^{-1}$
$= 4.40\ g\ CO_2$

Moles of base that match the acid

- The sample is 25.0 mL of 0.200 mol·L^{-1} hydrochloric acid.
- The neutralization $\text{HCl(aq)} + \text{NaOH(aq)} \longrightarrow \text{NaCl(aq)} + \text{H}_2\text{O(l)}$ uses matching coefficients of 1 and 1.

Oxygen gas and a shared table

- Hydrogen peroxide decomposition uses the ratio in $2\ H_2O_2 \longrightarrow 2\ H_2O + O_2$.
- A group table keeps every trial, and an industrial use of a ratio still leaves some problems open.

Chemistry 20

Unit D: Quantities in chemical change

Limiting reagents and percent yield

One reactant runs out first

- A reaction stops producing the intended substance when one reactant is used up, even if another reactant is still in the flask.
- The reactant that remains is leftover, and the reactant that disappeared sets the product amount.

Limiting reagent and percent yield

- Counted atoms on both sides of a balanced equation represent equal mass.
- The calculated maximum and the measured mass are compared by a percent.

Key terms

limiting reagent

The reactant that is consumed first and therefore sets the amount of product. (H_2 in the ammonia case)

excess reagent

The reactant that remains after the limiting reagent has been consumed. (0.333 mol N_2)

percent yield

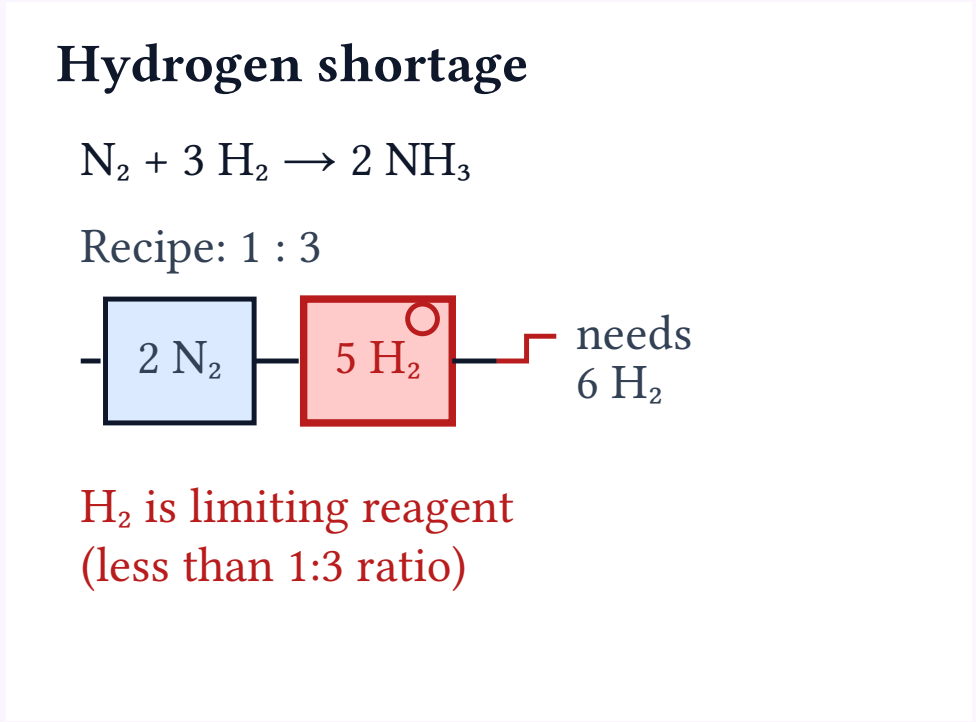
The actual mass divided by the theoretical mass, multiplied by 100. (80.0%)

actual yield

The mass of product measured after the reaction and the transfer are finished. (6.80 g)

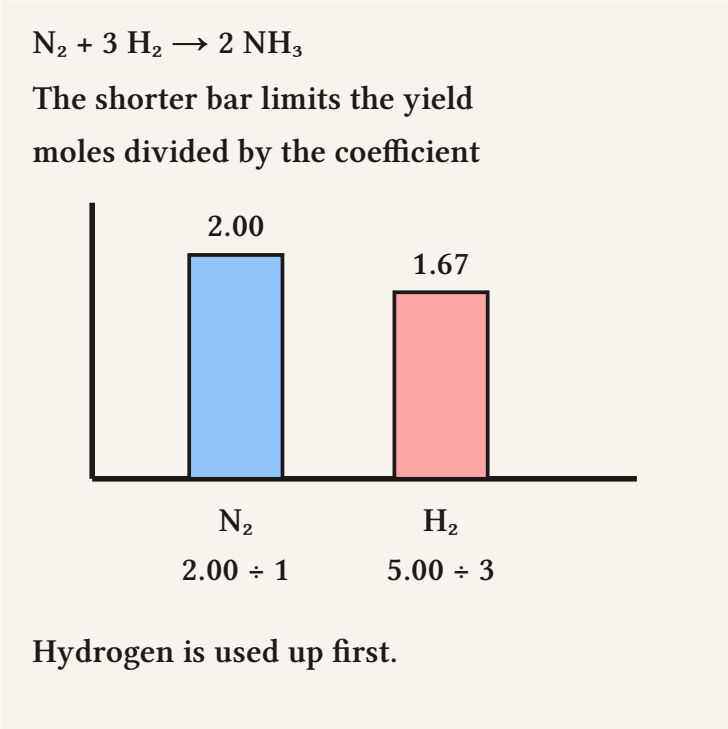
Equal mass, then a hydrogen shortage

- The equation $N_2 + 3\ H_2 \longrightarrow 2\ NH_3$ is the mass check and the recipe for the poured mixture.
- A mixture of 2.00 mol of nitrogen and 5.00 mol of hydrogen supplies less hydrogen than the 1 to 3 recipe demands.



Hydrogen sets the ammonia amount

- Divide each available amount by its coefficient and compare the quotients.
- The smaller quotient belongs to the reactant that is consumed first.



From 8.50 g calculated to 6.80 g measured

- The theoretical yield is the mass calculated from the limiting reagent.
- The actual yield is the mass measured after collection.

Yield

- The reactant with the smaller moles-per-coefficient value is consumed first.
- A percent below 100 names a gap between the balance and the calculation.

Chemistry 20

Unit D: Quantities in chemical change

Titration curves and indicators

The colour waits, then flips

- Base can drip into a strong acid for a long volume while the indicator colour barely changes.
- Across a few more drops the colour flips, and that flip is a signal on the curve.



The mole match and the colour change

- The curve is a plot of pH against the volume of strong base added to a strong monoprotic acid.
- The mole match and the indicator colour change are two events to mark on that plot.

Key terms

equivalence point

The mixture in which moles of H_3O+ from the acid equal moles of OH^- from the base. (pH 7 for this pair)

end point

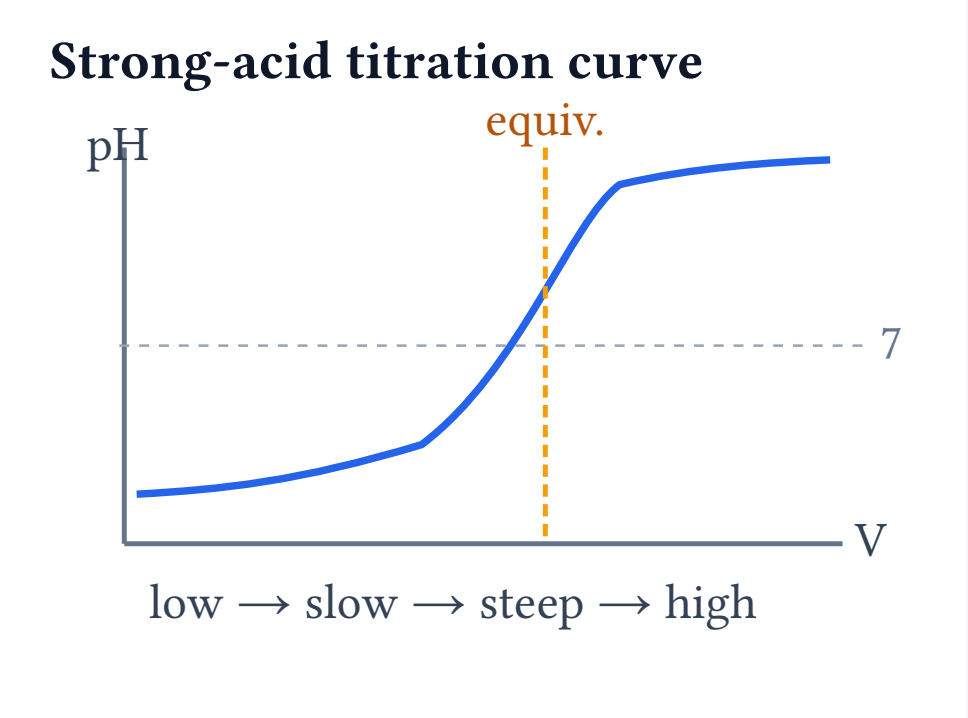
The volume at which the indicator changes colour during a titration. (bromothymol blue near pH 7)

titration curve

A graph of pH against the volume of titrant added. (steep jump near equivalence)

Four regions of the strong-acid curve

- The curve starts low, rises slowly, jumps steeply near the equivalence volume, and then levels high.
- For this acid-base pair the steep jump crosses pH 7.



Equal concentrations meet at equal volumes

- The acid sample is 25.00 mL of 0.100 mol·L^{-1} HCl.
- The titrant is 0.100 mol·L^{-1} NaOH, and the mole ratio in the neutralization is 1 to 1.

Indicators at the equivalence jump

- Bromothymol blue changes from yellow to blue across the steep region near pH 7.
- Phenolphthalein changes from colourless to pink slightly after pH 7.

Titration curves

- The equivalence point for this pair is the mole match at pH 7.
- The end point is the indicator colour change, which can sit very near that mole match.

Image credits

Lisa Simpson 23, Vinegar Titration - Color of the Phenolphthalein reacting to NaOH, CC BY-SA 4.0

Chemistry 20

Unit D: Quantities in chemical change

Stoichiometry in industry and the lab

Leftover feed is a cost

- A plant that pours a large excess of one reactant pays for material that ends up as leftover reactant.
- A higher percent of the calculated product collected means less of that feed was lost to an unfinished change or a side path.

Yield and by-products

- Industry uses stoichiometry to cut leftover reactant and to raise the percent of product collected.
- A lab plan names a concentration method, a predicted equivalence point, an indicator, and the WHMIS step.

Key terms

by-product

A second product, such as $SO_2(g)$ or carbon dioxide from a fuel, that still needs a risk and disposal decision. ($SO_2(g)$)

percent error

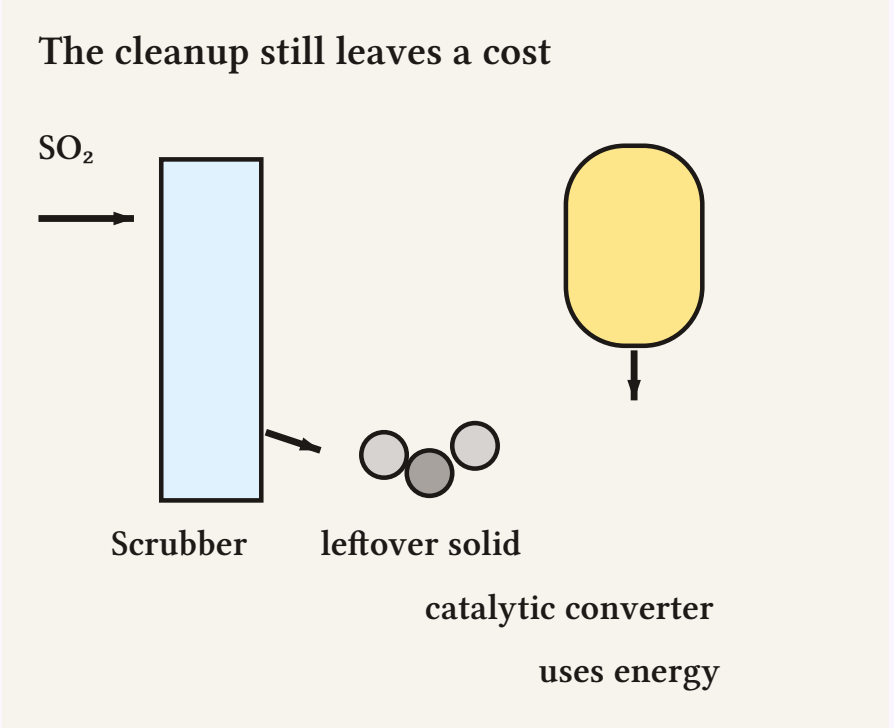
The positive difference between the measured mass and the theoretical mass, divided by the theoretical mass, times 100. (15.0%)

standard solution

A solution whose concentration is known well enough to find another concentration by titration. (0.100 $mol \cdot L^{-1}$ HCl)

Controls that still leave a cost

- A smokestack scrubber lowers $SO_2(g)$, and a catalytic converter lowers CO and NOx in exhaust.
- Each control meets an emission need and still carries a residue or an energy cost.



85.0 percent collected, 15.0 percent off

- The theoretical mass is 5.00 g and the collected mass is 4.25 g.
- Percent yield and percent error use those two masses in different fractions.

Titration plan

- A 25.00 mL acid sample near 0.100 mol·L^{-1} is expected to need about 25 mL of a base near 0.1 mol·L^{-1}.
- Bromothymol blue is the planned indicator, and a pH probe can log the curve.

A precipitate mass and two group results

- A dried precipitate mass can be turned into a solution concentration.
- Two groups can report different base concentrations, and both results stay in the shared table.