

## Topic 1 – Atomic structure and the periodic table

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## 1.1 A simple model of the atom, symbols, relative atomic mass, electronic charge and isotopes

### 1.1.1 Atoms, elements and compounds

**Atom** – smallest part of an element that can exist

**Element**

- Substance made of 1 type of atom
- Cannot be broken down chemically into simpler substance

**Compound**

- 2 or more elements chemically bonded in fixed properties
- Form / separate by chemical reactions

**Molecules** – collection of 2 or more atoms chemically bonded by covalent bonds

### 1.1.2 Mixtures

**Mixture**

- 2 or more elements / compounds not chemically bonded together
- Separated by physical processes
  - Not involved chemical reactions
  - No new substances made

**Separation techniques**




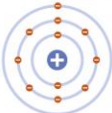

<b>Simple distillation</b>	<ul style="list-style-type: none"> <li>• Separates a liquid from a solution</li> </ul>	<ol style="list-style-type: none"> <li>1. Heat mixture until it boils &amp; evaporates into water vapour</li> <li>2. Water vapour rises up &amp; passes through condenser</li> <li>3. As condenser is cold, water vapour condenses back to water, which is collected in the flask</li> </ol>
<b>Fractional distillation</b>	<ul style="list-style-type: none"> <li>• Separates 2 liquids with similar boiling pt &amp; are miscible</li> </ul>	<ol style="list-style-type: none"> <li>1. Heat mixture</li> <li>2. Liquid with lower boiling pt evaporates into vapour</li> <li>3. Vapour rises up &amp; passes through fractionating column</li> <li>4. Vapour condenses back to water, which is collected in the flask</li> <li>5. Liquid with higher boiling pt starts to evaporate</li> <li>6. Crude oil is heated &amp; vaporised as it enters fractional distillation column</li> <li>7. Shorter chain lengths have weaker intermolecular forces &amp; lower boiling pt</li> <li>8. This means they will condense at top of column where it's cooler</li> <li>9. Longer chain lengths have stronger intermolecular forces &amp; higher boiling pt</li> <li>10. This means they will condense at bottom of column where it's hotter</li> <li>11. This is due to different chain lengths of hydrocarbons having different boiling pt so they can be separated &amp; tapped off at different levels as fractions</li> </ol>

<p><b>Filtration</b></p>	<ul style="list-style-type: none"> <li>Separates an insoluble solid from a liquid</li> </ul>	<ol style="list-style-type: none"> <li>Pour solid and liquid mixture in filter funnel which contains filter papers</li> <li>Liquid goes through filter paper but solid does not</li> </ol>
<p><b>Crystallisation</b></p>	<ul style="list-style-type: none"> <li>Separate soluble solid from solution</li> </ul>	<ol style="list-style-type: none"> <li>Pour acid into beaker</li> <li>Gently heat acid with Bunsen Burner till almost boiling</li> <li>Add base to acid one spatula at a time &amp; stir at the same time till base is in excess</li> <li>Filter excess base using filter paper &amp; funnel</li> <li>Pour solution into evaporating basin</li> <li>Heat gently over beaker of boiling water till half of solution remains</li> <li>Leave to cool and crystallise</li> <li>Pat dry using filter paper</li> </ol>
<p><b>Chromatography</b></p>	<ul style="list-style-type: none"> <li>Separate mixtures &amp; give info to help identify substance</li> </ul>	<ol style="list-style-type: none"> <li>Draw a pencil line on the paper.</li> <li>Place ink on the baseline in a dot.</li> <li>Place the paper into the beaker which has water in it. Make sure the baseline is above water level, so dye doesn't dissolve in water.</li> <li>Hang paper over edge of beaker to keep it right.</li> <li>Put a lid on.</li> <li>Wait for solvent to go up paper near the top.</li> <li>Remove paper &amp; let it dry.</li> <li>Draw circles around spots.</li> </ol>

### 1.1.3 The development of the model of the atom

**A HISTORY OF THE ATOM: THEORIES AND MODELS**

How have our ideas about atoms changed over the years? This graphic looks at atomic models and how they developed.

SOLID SPHERE MODEL	PLUM PUDDING MODEL	NUCLEAR MODEL	PLANETARY MODEL	QUANTUM MODEL
				
<p><b>JOHN DALTON</b></p> <p><b>1803</b></p> <p>Dalton drew upon the Ancient Greek idea of atoms (the word 'atom' comes from the Greek 'atomos' meaning indivisible). His theory stated that atoms are indivisible, those of a given element are identical, and compounds are combinations of different types of atoms.</p> <p><b>RECORDED ATOMS OF A PARTICULAR ELEMENT DIFFER FROM OTHER ELEMENTS</b></p> <p><b>NOTING ATOMS ARE INDIVISIBLE - THEY'RE COMPOSED FROM SUBATOMIC PARTICLES</b></p>	<p><b>J.J. THOMSON</b></p> <p><b>1904</b></p> <p>Thomson discovered electrons (which he called 'corpuscles') in atoms in 1897, for which he won a Nobel Prize. He subsequently produced the 'plum pudding' model of the atom. It shows the atom as composed of electrons scattered throughout a spherical cloud of positive charge.</p> <p><b>RECOGNISED ELECTRONS AS COMPONENTS OF ATOMS</b></p> <p><b>HE MODELLED, DIDN'T EXPLAIN LATER EXPERIMENTAL OBSERVATIONS</b></p>	<p><b>ERNEST RUTHERFORD</b></p> <p><b>1911</b></p> <p>Rutherford fired positively charged alpha particles at a thin sheet of gold foil. Most passed through with little deflection, but some deflected at large angles. This was only possible if the atom was mostly empty space, with the positive charge concentrated in the centre: the nucleus.</p> <p><b>REVEALED POSITIVE CHARGE WAS LOCATED IN THE NUCLEUS OF AN ATOM</b></p> <p><b>DID NOT EXPLAIN WHY ELECTRONS REMAIN IN ORBIT AROUND THE NUCLEUS</b></p>	<p><b>NIELS BOHR</b></p> <p><b>1913</b></p> <p>Bohr modified Rutherford's model of the atom by stating that electrons moved around the nucleus in orbits of fixed sizes and energies. Electron energy in this model was quantised; electrons could not occupy values of energy between the fixed energy levels.</p> <p><b>PROPOSED STABLE ELECTRON ORBITS EXPLAINED THE EMISION SPECTRA OF SOME ELEMENTS</b></p> <p><b>MOVING ELECTRONS RELEASED ENERGY AND COLLAPSE INTO THE NUCLEUS MODEL DID NOT WORK WELL FOR HEAVIER ATOMS</b></p>	<p><b>ERWIN SCHRÖDINGER</b></p> <p><b>1926</b></p> <p>Schrödinger stated that electrons do not move in set paths around the nucleus, but in waves. It is impossible to know the exact location of the electrons; instead, we have 'clouds of probability' called orbitals, in which we are more likely to find an electron.</p> <p><b>SOME ELECTRONS DON'T MOVE AROUND THE NUCLEUS IN ORBITS, BUT IN CLOUDS WHERE THEIR POSITION IS UNCERTAIN</b></p> <p><b>STILL MOSTLY ACCEPTED AS THE MOST ACCURATE MODEL OF THE ATOM</b></p>

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- John Dalton** – tiny hard sphere & indivisible
- JJ Tomson** – 'Plum Pudding Model'

#### Experiment

- Apply high voltages to gases at low pressure on beams of particles

#### Results

- Attract on +ve charge
- Show atom contains -ve charged particles (electrons)

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- -ve charged  $e^-$  embedded in a cloud of +ve charge  $\rightarrow$  atom is neutral

### 3. Rutherford – ‘Alpha Particle Scattering Experiment’

#### Experiment

- Fired +ve alpha particle beams on extremely thin gold foil

#### Results

- Straight through  $\rightarrow$  most atom is empty spaced
- Slightly deflected  $\rightarrow$  nucleus is +ve charged
- Deflected by  $>90^\circ$   $\rightarrow$  nucleus is +ve charged

- +ve nucleus concentrate mass of atom at centre of atom
- -ve  $e^-$  exist in cloud around nucleus

### 4. Neil Bohr – ‘Nuclear Model’

#### Experiment

- Notice light given out when atoms were heated only had specific amount of energy

#### Results

- $e^-$  orbit nucleus in specific energy levels at specific distances with nothing in between

### 5. James Chadwick – proved neutrons existed in nucleus in 1932

## 1.1.4 Relative electrical charges of subatomic particles

## 1.1.5 Size and mass of atoms

Name of particle	Relative mass	Electric charge
Proton	1	+1
Neutron	1	0
Electron	0 or $\frac{1}{1836}$	-1

#### Why doesn't an atom have charge?

- Relative electrical charge
  - Electrons: -1, protons :+1
- No of electrons = no of protons

Atom radius = 0.1nm ( $1 \times 10^{-10}$ m)

Nucleus radius =  $\frac{1}{10000}$  of an atom ( $1 \times 10^{-14}$ m)

#### Formulae

No of neutrons = mass no – atomic no = 23-11 = 12

Atomic no = no of protons = 11

Mass no = protons + neutrons

23
Na
sodium
11

Key
relative atomic mass
atomic symbol
name
atomic (proton) number

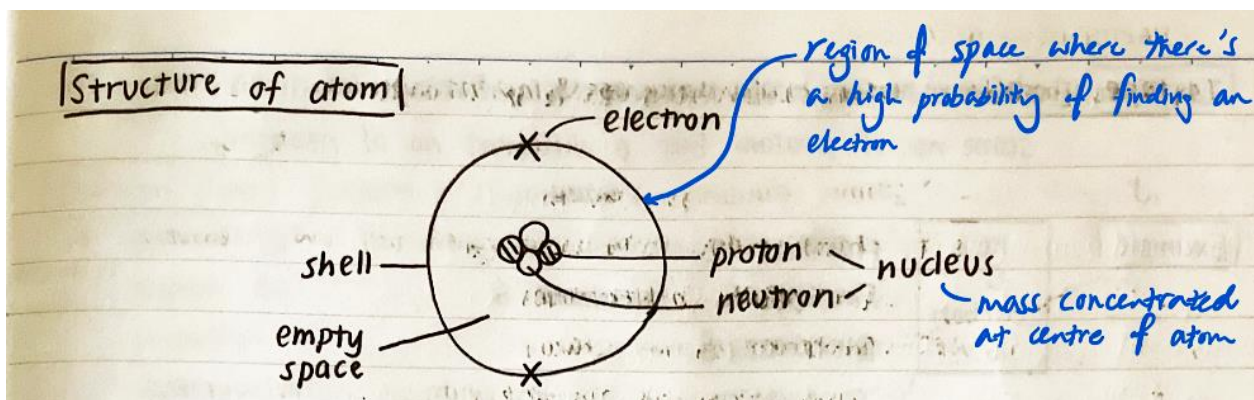
## 1.1.6 Relative atomic mass

$$\text{Relative atomic mass} = \frac{\text{sum of (isotope abundance} \times \text{isotope mass no)}}{100 \text{ (total no at atoms)}}$$

#### High relative atom mass

- Less waste products
- Less pollutants

## 1.1.7 Electronic structure



Explain why fluorine and chlorine are in the same group of the period table. Give the electronic structures of fluorine and chlorine in your explanation. (2)

- Isotope is different forms of the same element, which have the same no of protons but different no of neutrons
- The electronic structure of fluorine is 2,7 and chlorine is 2,8,7
- F & Cl both has 7e<sup>-</sup> in outer shell

Explain why  $^{12}_6\text{C}$  and  $^{14}_6\text{C}$  are isotopes of carbon. You should refer to the numbers of sub-atomic particles in the nucleus of each isotope. (3)

- Isotope is different forms of the same element, which have the same no of protons but different no of neutrons
- They both have 6 protons
- $^{12}\text{C}$  has 6 neutrons,  $^{14}\text{C}$  has 8 neutrons

## 1.2 The periodic table

## 1.2.1 The periodic table

**The Periodic Table of Elements**

Group no. tells you the number of electrons in the outer shell

The relative atomic mass is made up of the total number of protons and neutrons

Proton number is the same as the total number of electrons

Key: relative atomic mass, atomic symbol, name, atomic (proton) number

Alkali metals		Alkali earth metals		Transition metals													Halogens		Noble gases																																																																																										
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																																																																																												
7 Li lithium 3	9 Be beryllium 4	11 Na sodium 11	12 Mg magnesium 12	13 Al aluminium 13	14 Si silicon 14	15 P phosphorus 15	16 S sulfur 16	17 Cl chlorine 17	18 Ar argon 18	19 K potassium 19	20 Ca calcium 20	21 Sc scandium 21	22 Ti titanium 22	23 V vanadium 23	24 Cr chromium 24	25 Mn manganese 25	26 Fe iron 26	27 Co cobalt 27	28 Ni nickel 28	29 Cu copper 29	30 Zn zinc 30	31 Ga gallium 31	32 Ge germanium 32	33 As arsenic 33	34 Se selenium 34	35 Br bromine 35	36 Kr krypton 36	37 Rb rubidium 37	38 Sr strontium 38	39 Y yttrium 39	40 Zr zirconium 40	41 Nb niobium 41	42 Mo molybdenum 42	43 Tc technetium 43	44 Ru ruthenium 44	45 Rh rhodium 45	46 Pd palladium 46	47 Ag silver 47	48 Cd cadmium 48	49 In indium 49	50 Sn tin 50	51 Sb antimony 51	52 Te tellurium 52	53 I iodine 53	54 Xe xenon 54	55 Cs caesium 55	56 Ba barium 56	57 La* lanthanum 57	58 Ce cerium 58	59 Pr praseodymium 59	60 Nd neodymium 60	61 Pm promethium 61	62 Sm samarium 62	63 Eu europium 63	64 Gd gadolinium 64	65 Tb terbium 65	66 Dy dysprosium 66	67 Ho holmium 67	68 Er erbium 68	69 Tm thulium 69	70 Yb ytterbium 70	71 Lu lutetium 71	72 Hf hafnium 72	73 Ta tantalum 73	74 W tungsten 74	75 Re rhenium 75	76 Os osmium 76	77 Ir iridium 77	78 Pt platinum 78	79 Au gold 79	80 Hg mercury 80	81 Tl thallium 81	82 Pb lead 82	83 Bi bismuth 83	84 Po polonium 84	85 At astatine 85	86 Rn radon 86	87 Fr francium 87	88 Ra radium 88	89 Ac* actinium 89	90 Th thorium 90	91 Pa protactinium 91	92 U uranium 92	93 Np neptunium 93	94 Pu plutonium 94	95 Am americium 95	96 Cm curium 96	97 Bk berkelium 97	98 Cf californium 98	99 Es einsteinium 99	100 Fm fermium 100	101 Md mendelevium 101	102 No nobelium 102	103 Lr lawrencium 103	104 Rf rutherfordium 104	105 Db dubnium 105	106 Sg seaborgium 106	107 Bh bohrium 107	108 Hs hassium 108	109 Mt meitnerium 109	110 Ds darmstadtium 110	111 Rg roentgenium 111	112 Cn copernicium 112	113 Nh nihonium 113	114 Fl flerovium 114	115 Mc moscovium 115	116 Lv livermorium 116	117 Ts tennessine 117	118 Og oganeson 118

\* The Lanthanides (atomic numbers 58 – 71) and the Actinides (atomic numbers 90 – 103) have been omitted.

Relative atomic masses for Cu and Cl have not been rounded to the nearest whole number.

REMEMBER: The relative atomic mass is the average mass of all the isotopes of an element. All the others have been rounded to a whole number.

### Arrangement – order of increasing atomic no

- Elements with similar properties are in **columns**, aka **groups**

### Why is the table called periodic table?

- Similar properties occur at regular intervals

### Why are the elements in the same group?

- Same no of e- on outer shell
- Similar chemical & physical properties

## 1.2.2 Development of the periodic table

### 1. Antoine Lavoisier – has compounds

### 2. John Newlands

- Arranged strictly in octaves by atomic weights (but no chemical properties)
- Realised every 8<sup>th</sup> element reacts in similar way – ‘Law of octaves’

### 3. Dimitri Mendeleev

- Arranged in order of atomic mass but changed some order base on atomic weight
  - Isotopes proved correct
- Left gaps for elements that he though hadn’t been discovered

#### Why Mendeleev left gaps?

- For undiscovered elements so elements with similar properties can be placed tgt / pattern fit
- Predicted properties of missing elements

Later on, elements discovered atomic properties matches predictions

### 4. Modern – organized in atomic no

## 1.2.3 Metals and non-metals

### Properties

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Metals (+ve ions)	Non-metals (-ve ions)
<ul style="list-style-type: none"> <li>• High melting points</li> <li>• High density</li> <li>• Conduct electricity</li> <li>• Shiny, malleable, sonorous</li> </ul>	<ul style="list-style-type: none"> <li>• Low melting points</li> <li>• Low density</li> <li>• Electrical insulator</li> <li>• Dull, brittle</li> </ul>

## 1.2.4 Group 0 (Noble gases)

### Properties

- Non-metal
- Colorless gases, low melting point, low density, not flammable

### Why are elements in group 0 unreactive & don't form molecules easily? (1)

- Have full & stable outer shell

### Why does the boiling point increase down the group? (3)

- ↑ no of shell / size of atom
- Intermolecular force between atom become stronger
- Need more energy to overcome force

## 1.2.5 Group 1 (Alkali metals)

- Metals
- Soft, low melting point, less dense (so top 3 elements float on water)
- +1 ion → lose e<sup>-</sup> → form ionic compound
  - White solids, dissolve in water, form colourless solutions

### Reaction with oxygen

Metal<sub>(s)</sub> + oxygen<sub>(g)</sub> → metal oxide<sub>(s)</sub>

Metal	Equation	Flame colour
Lithium	Lithium + oxygen → lithium oxide $4\text{Li} + \text{O}_2 \rightarrow 2\text{Li}_2\text{O}$	Crimson red
Sodium	Sodium + oxygen → sodium oxide $4\text{Na} + \text{O}_2 \rightarrow 2\text{Na}_2\text{O}$	Yellow
Potassium	Potassium + oxygen → potassium oxide $4\text{K} + \text{O}_2 \rightarrow 2\text{K}_2\text{O}$	Lilac

### Reaction with chloride

- Exothermic reaction
- Form ionic salt

Metal<sub>(s)</sub> + chlorine<sub>(g)</sub> → metal chloride<sub>(s)</sub>

Metal	Equation
Lithium	Lithium + chlorine → lithium chloride $2\text{Li} + \text{Cl}_2 \rightarrow 2\text{LiCl}$
Sodium	Sodium + chlorine → sodium chloride $2\text{Na} + \text{Cl}_2 \rightarrow 2\text{NaCl}$

Potassium	Potassium + chlorine → potassium chloride $2K + Cl_2 \rightarrow 2KCl$
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### Reaction with water

**Metal<sub>(s)</sub> + water<sub>(l)</sub> → metal hydroxide<sub>(aq)</sub> + hydrogen<sub>(g)</sub>**

Metal	Equation	Observation
Lithium	Lithium + water → lithium hydroxide + hydrogen $2Li + 2H_2O \rightarrow 2LiOH + H_2$	<ul style="list-style-type: none"> <li>• Move around on surface</li> <li>• Fizzes steadily</li> <li>• Slowly becomes small till it disappears</li> </ul>
Sodium	Sodium + water → sodium hydroxide + hydrogen $2Na + 2H_2O \rightarrow 2NaOH + H_2$	<ul style="list-style-type: none"> <li>• Move around on surface</li> <li>• Melts to form a ball</li> <li>• Fizzes rapidly</li> <li>• Quickly becomes small till it disappears</li> </ul>
Potassium	Potassium + water → potassium hydroxide + hydrogen $2K + 2H_2O \rightarrow 2KOH + H_2$	<ul style="list-style-type: none"> <li>• Move around on surface</li> <li>• Quickly melts to form a ball</li> <li>• Fizzes &amp; burin violently with sparks &amp; lilac flame</li> <li>• Disappears rapidly</li> </ul>

### Why does the reactivity increase down the group? (4)

- ↑ no of shell
- ↑ electron shielding
- ↓ attraction between +ve nucleus & -ve outer e-
- Outer e- requires less energy to remove
- Atom is more reactive

## 1.2.6 Group 7 (Halogens)

- Non-metals
- Consist of diatomic molecules (2 elements chemically combined using covalent bond)
- -1 ion → gain e- → fill outer shell → stable
- Form molecular compounds with non-metallic elements
- Low melting point → coz weak force between molecules
- Density, melting point increases down the group

### Why does the reactivity decrease down the group? (4)

- ↑ no of shell
- ↑ size → e- further from nucleus
- ↑ electron shielding
- ↓ attraction between +ve nucleus & -ve outer e-
- ↓ energy to attract e- to form -ve ion
- e- easily gained
- Atom is less reactive

Halogen	Appearance & state at room temp	Colour in water
---------	---------------------------------	-----------------



Fluorine	Yellow gas	-
Chlorine	Pale yellow – green gas	Pale green
Bromine	Red – brown liquid	Orange
Iodine	Purple – black solid	Brown

### Displacement reaction

- More reactive displace less reactive elements
- $F > Cl > Br > I$
- **More reactive(s) + compound(aq) → less reactive(s) + compound(aq)**

	KI	KBr	KCl
Cl <sub>2</sub>	Orange $2KI + Cl_2 \rightarrow 2KCl + I_2$ $2I^- + Cl_2 \rightarrow 2Cl^- + I_2$	Pale yellow $2KBr + Cl_2 \rightarrow 2KCl + I_2$ $2Br^- + Cl_2 \rightarrow 2Cl^- + I_2$	×
Br <sub>2</sub>	Yellow orange $2KI + Br_2 \rightarrow 2KCl + I_2$ $2I^- + Br_2 \rightarrow 2Cl^- + I_2$	×	Displaced (no reaction)
I <sub>2</sub>	×	Displaced (no reaction)	Displaced (no reaction)

## 1.3 Properties of transition metals (chemistry only)

### 1.3.1 Comparison with Group 1 elements

What are the **physical** differences between group 1 & transition elements? (3)

Group 1	Transition metals
<ul style="list-style-type: none"> <li>• Low melting point</li> <li>• Low density</li> <li>• Soft</li> </ul>	<ul style="list-style-type: none"> <li>• High melting point</li> <li>• High density</li> <li>• Strong, hard</li> </ul>

What are the **chemical** differences between group 1 & transition elements? (3)

Group 1	Transition metals
<ul style="list-style-type: none"> <li>• Very reactive</li> <li>• Not used as catalysts</li> <li>• Form colourless / white compound</li> <li>• Only form +1 ions</li> </ul>	<ul style="list-style-type: none"> <li>• Low reactivity</li> <li>• Used as catalysts</li> <li>• Form coloured compound</li> <li>• Ions with different charges</li> </ul>

### 1.3.2 Typical properties (transition metals)

#### Properties

- High melting point, high density, strong, hard
- Low reactivity, used as catalysts, form coloured compound, ions with different charges

#### Uses as catalysts

- **Manganese (IV) oxide** increases decomposition of hydrogen peroxide to oxygen & water

GCSE/IGCSE Chemistry notes

Atomic structure and the periodic table

- $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$
- **Iron** for Haber process makes ammonia
  - $\text{N}_2 + 3\text{H}_2 \rightleftharpoons 2\text{NH}_3$
- **Nickel** for manufacture of margarine

## Others - Ions

**Ions** – a charged particle produced by loss / gain of mass

### Positive ions

Name	Formula
Hydrogen	$\text{H}^+$
Sodium	$\text{Na}^+$
Silver	$\text{Ag}^+$
Potassium	$\text{K}^+$
Lithium	$\text{Li}^+$
Ammonium	$\text{NH}_4^+$
Barium	$\text{Ba}^{2+}$
Calcium	$\text{Ca}^{2+}$
Copper(II)	$\text{Cu}^{2+}$
Magnesium	$\text{Mg}^{2+}$
Zinc	$\text{Zn}^{2+}$
Lead	$\text{Pb}^{2+}$
Iron(II)	$\text{Fe}^{2+}$
Iron(III)	$\text{Fe}^{3+}$
Aluminium	$\text{Al}^{3+}$

### Negative ions

Name	Formula
Chloride	$\text{Cl}^-$
Bromide	$\text{Br}^-$
Fluoride	$\text{F}^-$
Iodide	$\text{I}^-$
Hydroxide	$\text{OH}^-$
Nitrate	$\text{NO}_3^-$
Oxide	$\text{O}^{2-}$
Sulfide	$\text{S}^{2-}$
Sulfate	$\text{SO}_4^{2-}$
Carbonate	$\text{CO}_3^{2-}$