Electrolysis

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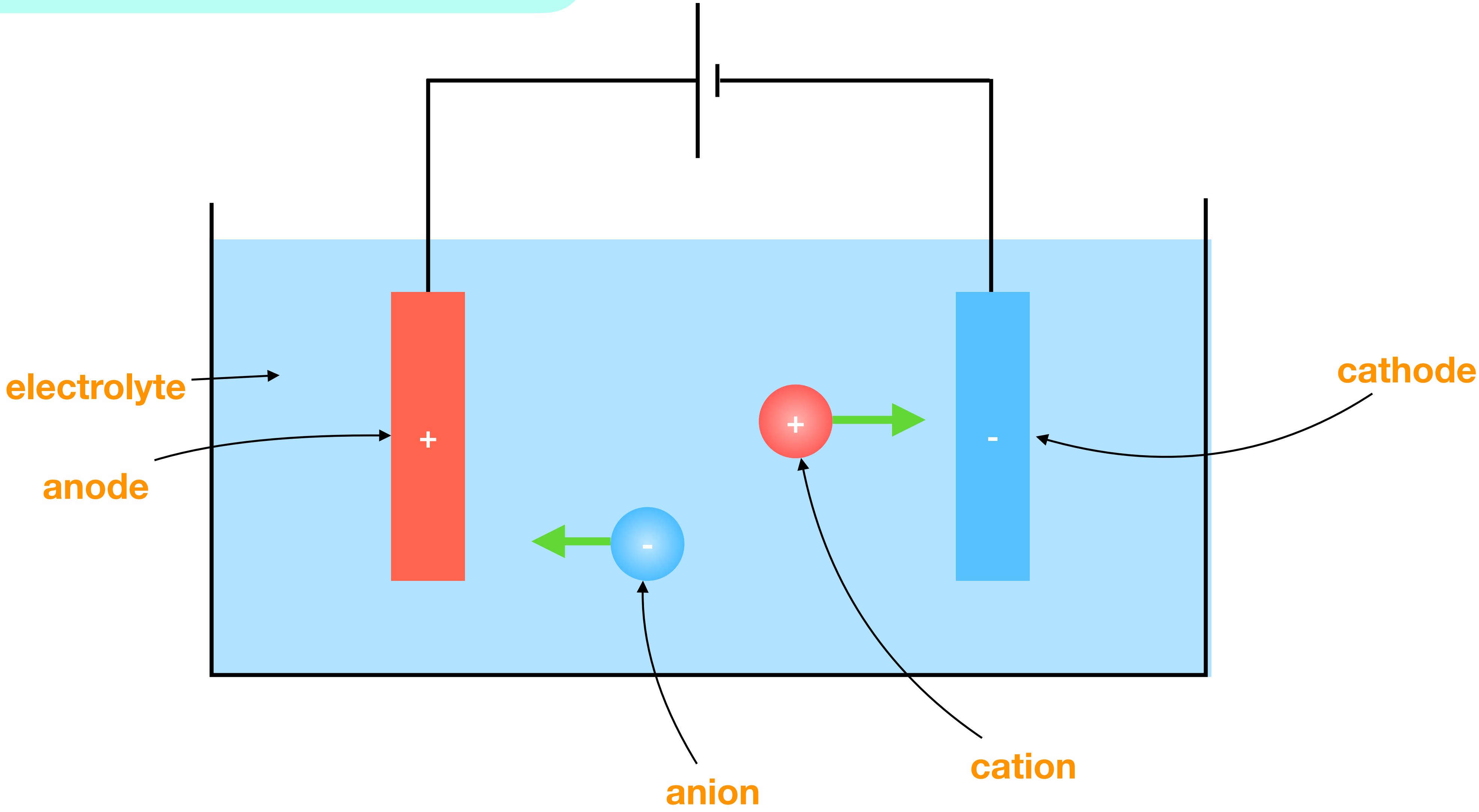
electrical splitting

Electrolysis is the splitting of chemical compounds by passing an electrical current through them.

The ions need to be free to move about so we always make sure the compound is in liquid form; either dissolved or molten.

Electrolysis



what’s going on?

Often the electrical currents we study are the flow of electrons, this time it is the flow of positive and negative atoms called ions.

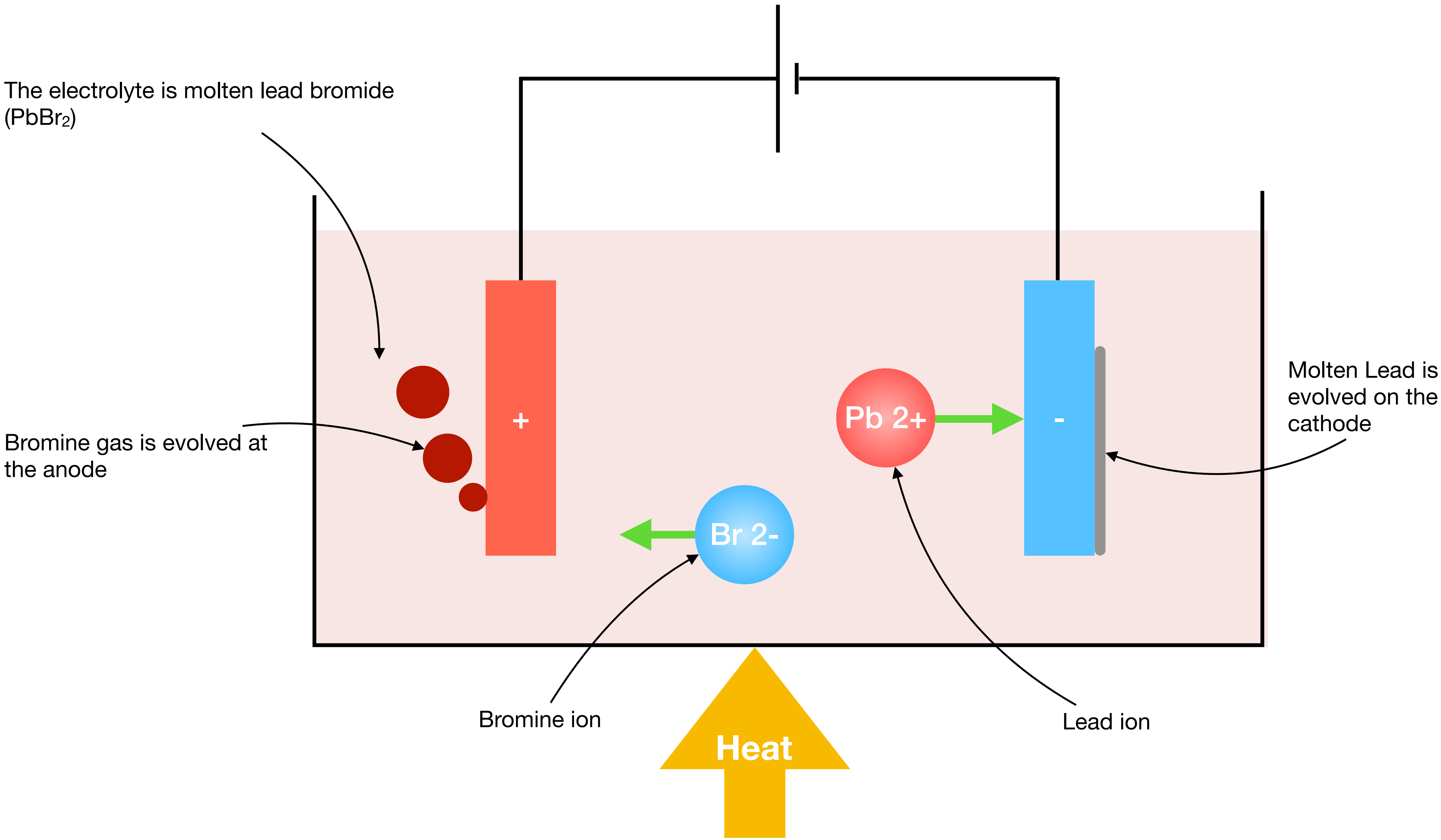
Ions are atoms which have gained or lost electrons and as a result have different numbers of electrons to protons making them charged.

We say that negative ions, anions, 'migrate' to the positively charged anode.

Positive ions, cations, migrate to the negatively charged cathode.

The ions attach themselves to the electrode so electrolysis is a good method for separating substances.

Molten Lead Bromide



A few quick things

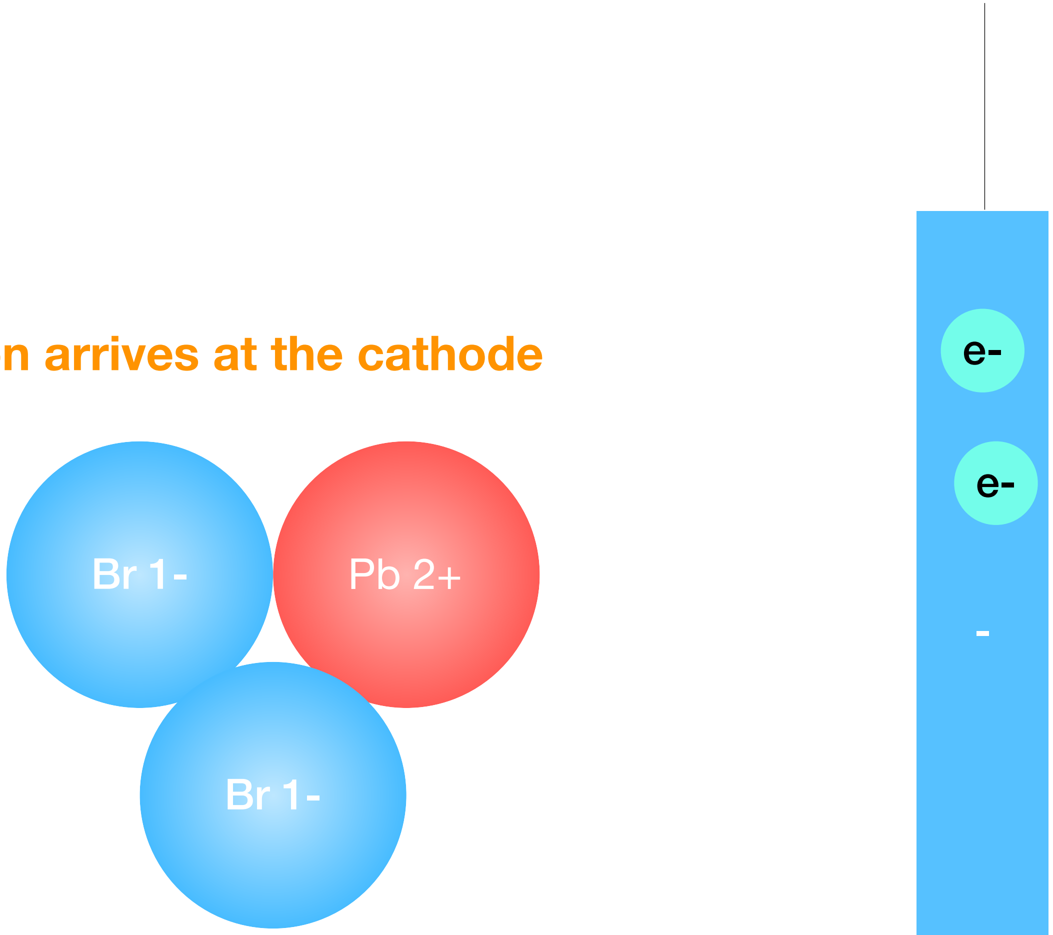
$PbBr_2$ = Lead bromide

Lead bromide is an ionic salt i.e. a metal and non-metal ionically bonded together.

To make electrolysis possible the Pb and Br ions need to be able to move freely so the lead bromide must be molten.

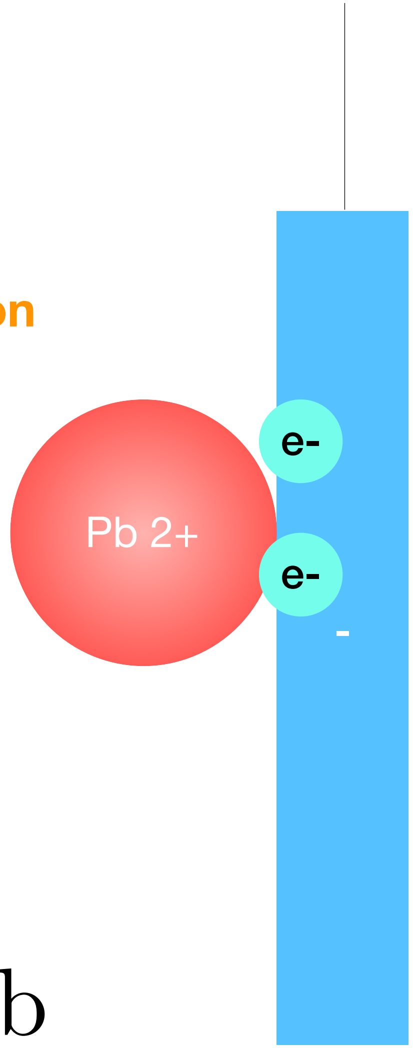
at the cathode

the lead ion arrives at the cathode



at the cathode

2 electrons begin
orbiting the lead ion
and reduce it

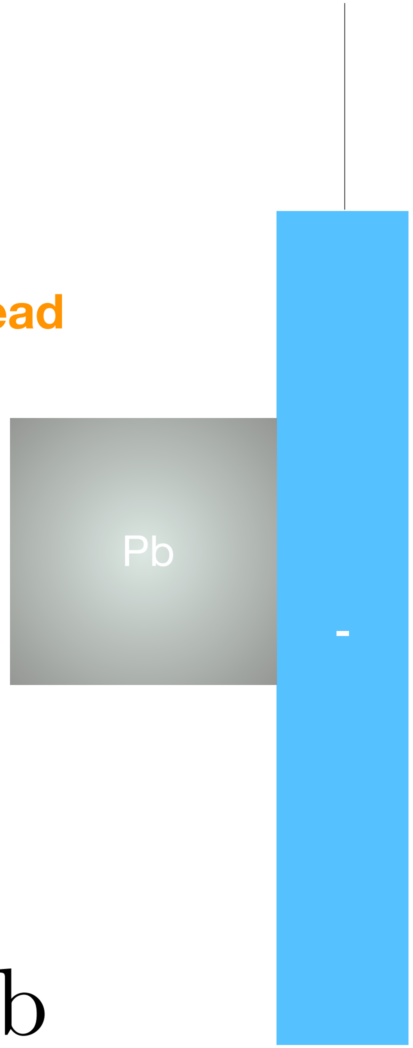


the half equation for the cathode

$$Pb^{2+} + 2e^{-} \longrightarrow Pb$$

at the cathode

the ion becomes an atom of lead

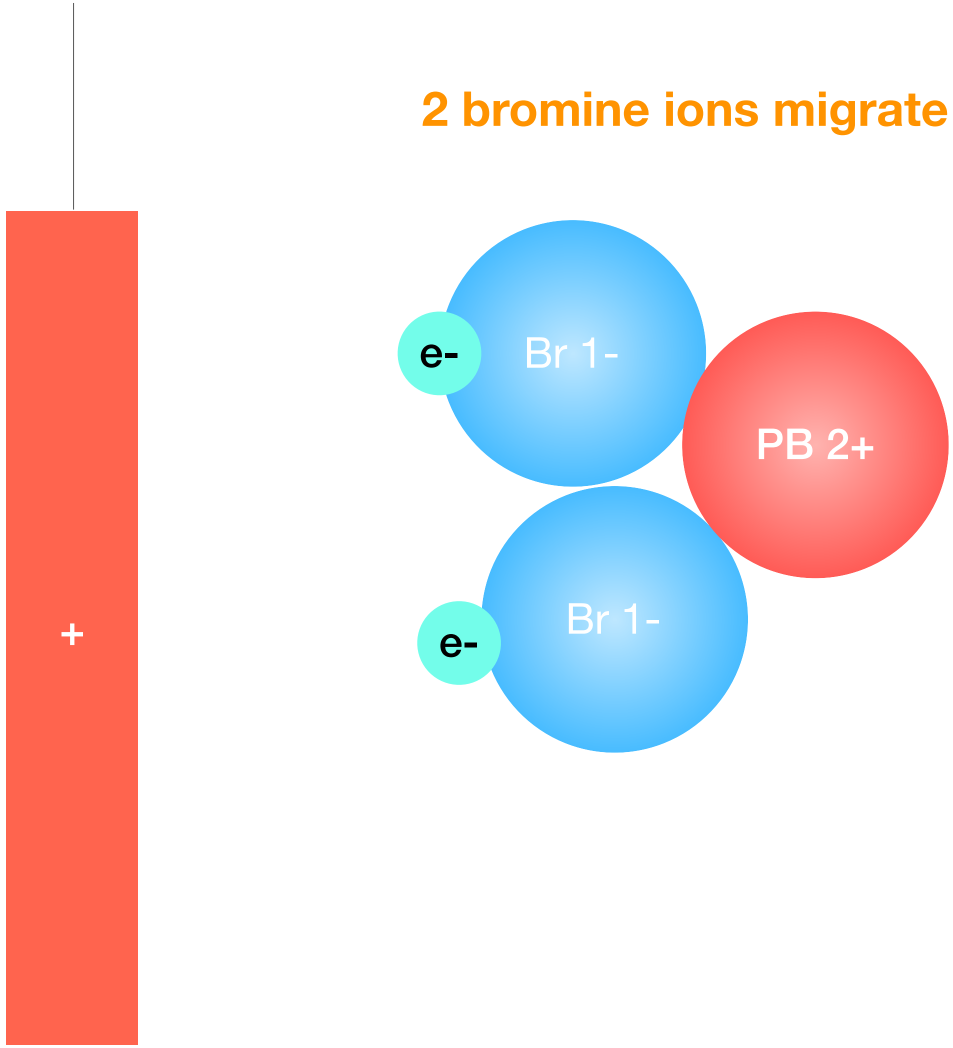


the half equation for the cathode

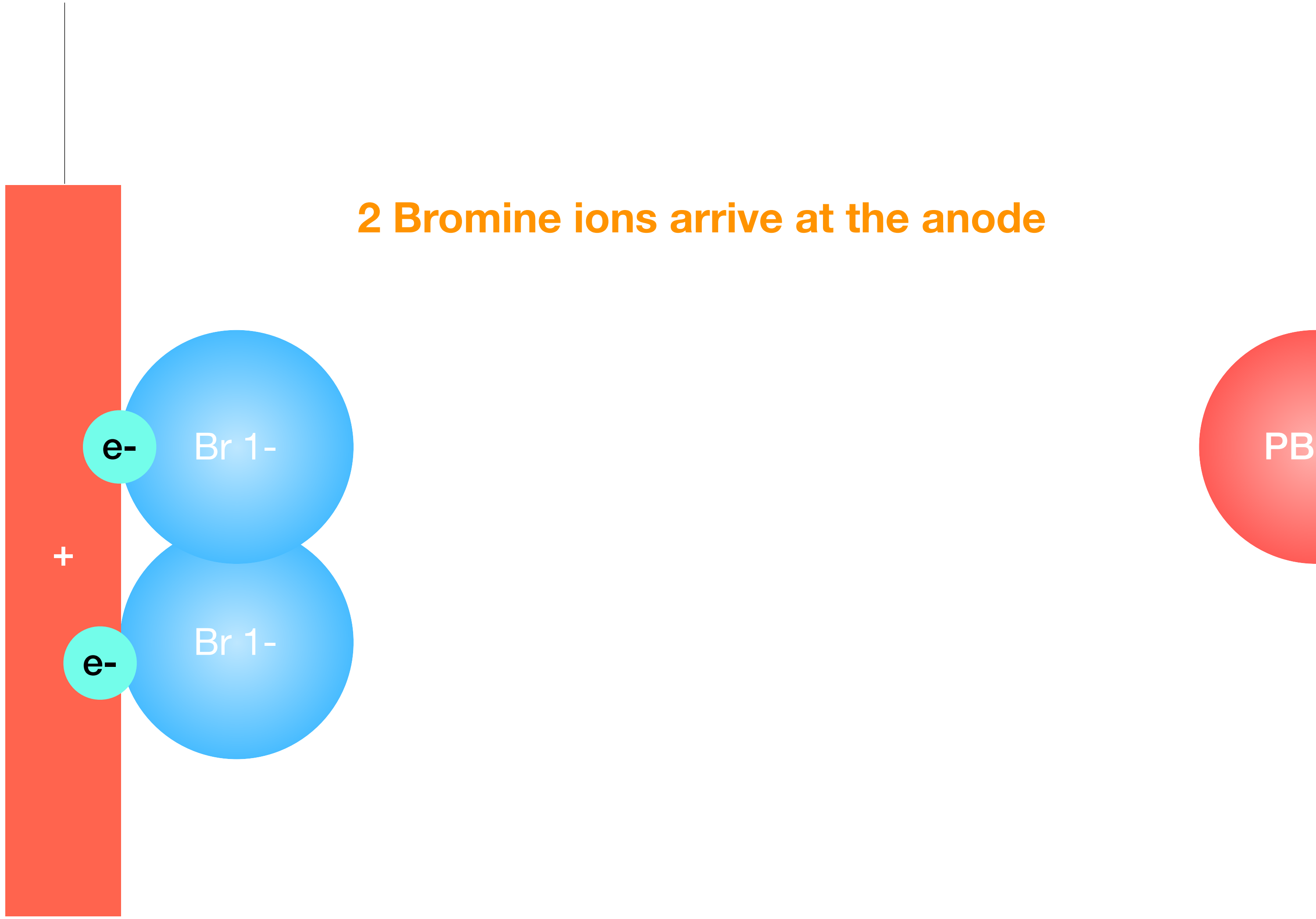
$$Pb^{2+} + 2e^{-} \longrightarrow Pb$$

at the anode

2 bromine ions migrate to the anode

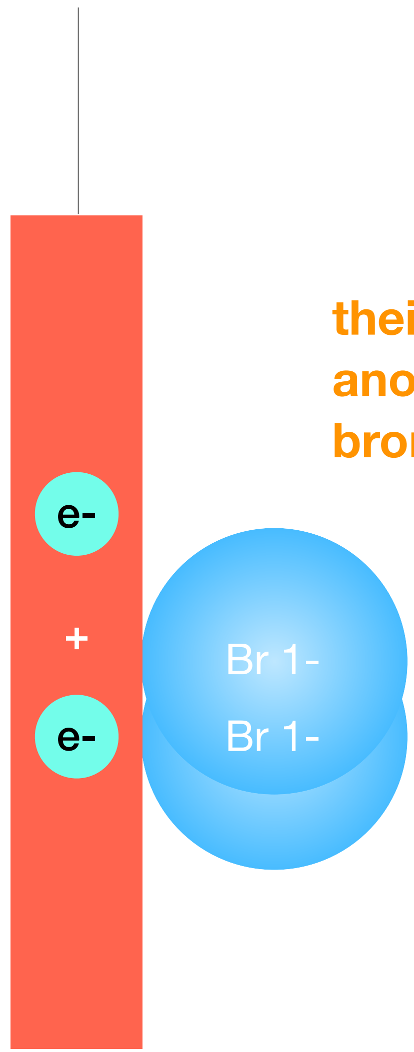


at the anode



2 Bromine ions arrive at the anode

at the anode

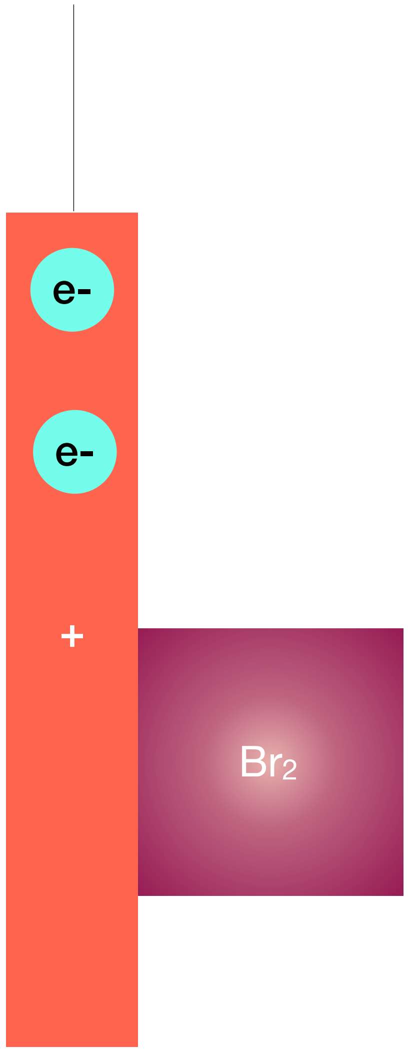


their electrons enter the anode, oxidising the bromide ions

Half equation for the anode

$$2\mathrm{Br}^- - 2\mathrm{e}^- \longrightarrow \mathrm{Br}_2$$

at the anode



the bromide ions bond
to form a Bromine atom

notes on half equations

half equation for the anode

Bromine is formed

$$2Br^- - \boxed{2e^-} \longrightarrow \boxed{Br_2}$$

half equation for the cathode

these terms have the same charge

$$\boxed{Pb^{2+}} + \boxed{2e^-} \longrightarrow \boxed{Pb}$$

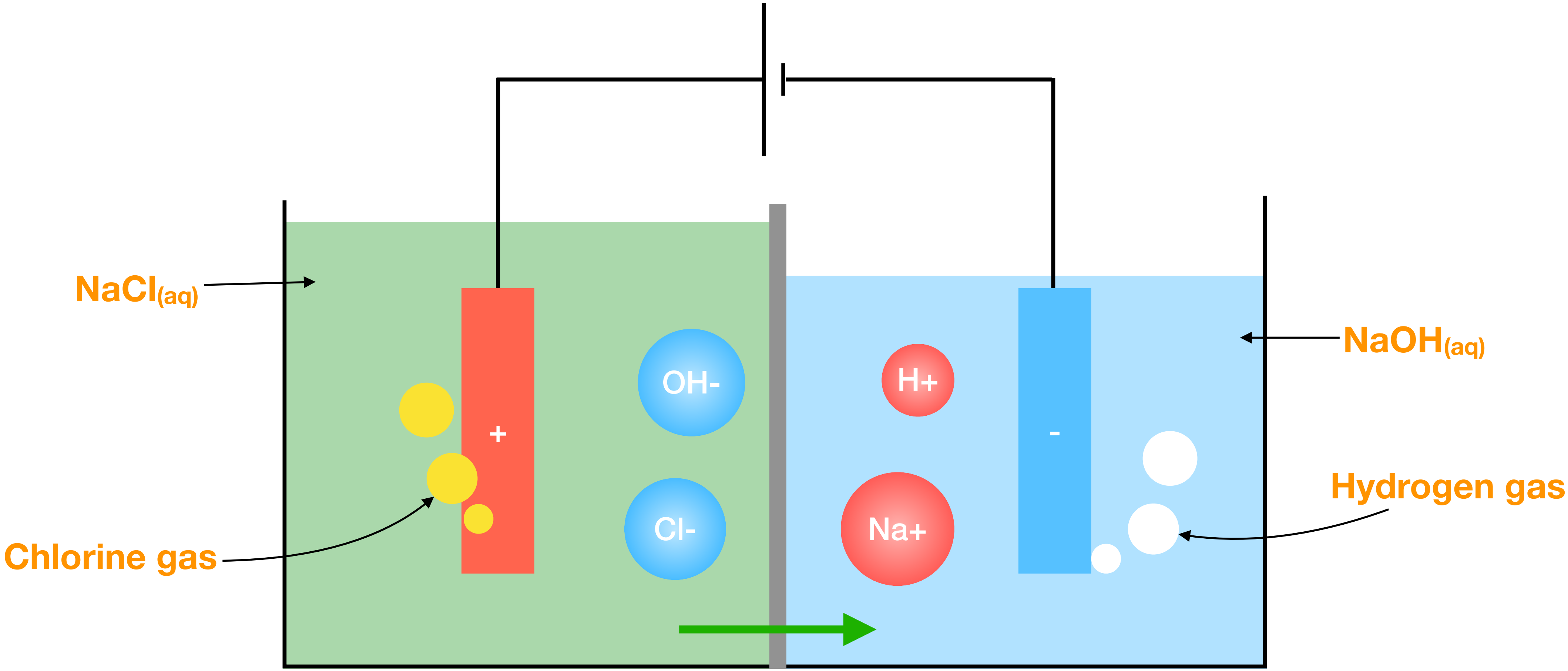
Lead is formed

the same number of electrons in each equation but opposite signs. This is because charge is incompressible and can't build up anywhere in the circuit.

Remember: charge in = charge out in a circuit

draw a cartoonish dot and cross diagram for this to make sure you understand it

Brine - NaCl (aq)



One way flow of NaCl solution through diaphragm

NaCl (aq) = “aqueous sodium chloride” = “salt water” = “brine”

half equations

half equation for the anode

Chlorine gas is formed

$$2Cl^- - 2e^- \longrightarrow \boxed{Cl_2}$$

half equation for the cathode

Hydrogen gas is formed

$$2H^+ + 2e^- \longrightarrow \boxed{H_2}$$

a few details

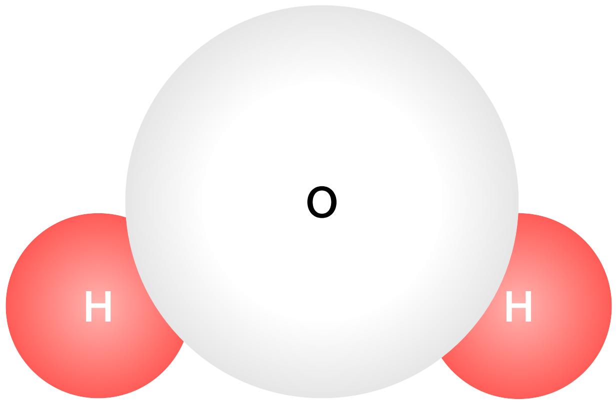
The diaphragm and higher water level on the anode side prevent NaOH solution from reacting with the Cl gas, otherwise this would form bleach (Sodium Hypochlorite).

The OH ions flow through the diaphragm and combine with the Na ions at the cathode to for NaOH solution which is strongly alkaline.

It is important to keep the Cl and H gases separate becuase their mixture explodes on exposure to sunlight or heat.

dissociation of water

in this experiment water dissociates into an H+ ion and an OH- ion so these need to appear in our equations.



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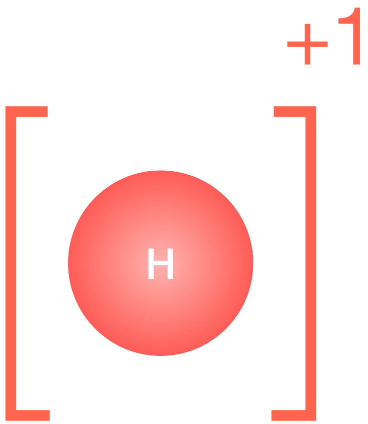
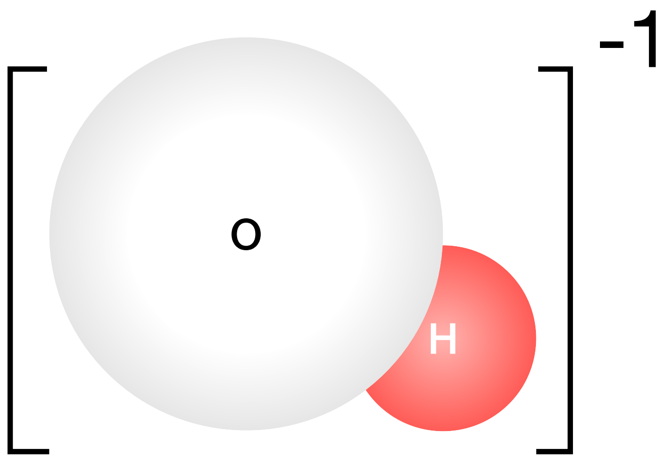


an H+ ion, a proton



a OH- ion is called an hydroxide ion

electrolysis calculations

More challenging electrolysis questions involve figuring out what mass of Hydrogen (for example) we will produce if we pass a current through a solution of NaCl for a certain amount of time.

Make sure you know these things:

Current is the flow of charge

Charge is measured in Coulombs

Current is measured is Coulombs per second

Instead of saying Coulombs per second we say Ampères or “Amps”

Just Checking

A current of 7 Ampères flowing around a circuit means that:

At every point on that circuit 7 Coulombs of charge go past each second.

So in 1 hour 60x60x7 Coulombs would pass by each point on the circuit.

Each electron holds -1.6x10-19 Coulombs. Very little.

Make sure this makes sense to you. Look it up online if you're unsure.

Example: PbBr_2

“If I pass a current of 10 Amps through molten PbBr for 1 hour what mass of Lead accumulates at the cathode?”

1) From the half equation we know we need 2 electrons to get 1 Pb atom on the Cathode. That’s because Pb forms 2+ ions.

2) So if the current gave 2 electrons per second that would yield 1 atom of Pb per second.

3) so that would mean a current of

$$2 \times 1.6 \times 10^{-19} = 3.2 \times 10^{-19}\mathrm{A}$$

For 1 second gives…

1 atom of lead which is:

$$207.2 \quad \div \quad 6.023 \times 10^{23} \quad = \quad 3.44 \times 10^{-22}\text{grams}$$

Remember

mass (g) = R.A.M x number of moles

number of particles = number of moles x 6.023x1023

These numbers are perfectly true but a bit too small to be useful.
Let’s actually answer the question now.

Strategy:

1) number of electrons

2) number of Pb atoms

3) mass of Pb

Strategy:

1) number of electrons

total charge transferred / charge of each electron

Total charge transferred:

$$10 \text{ Amps} \times 60 \times 60 = 36,000 \text{ Coulombs}$$

So number of electrons =

$$36,000 \div 1.6 \times 10^{-19} \; = \; 2.25 \times 10^{23}$$

2) number of Pb atoms

3) mass of Pb

Strategy:

1) number of electrons

$$36,000 \div 1.6 \times 10^{-19} \; = \; 2.25 \times 10^{23}$$

2) number of Pb atoms

number of Pb atoms = number of electrons / 2

$$1.125 \times 10^{23} \text{ atoms}$$

3) mass of Pb

Strategy:

1) number of electrons

$$36,000 \div 1.6 \times 10^{-19} \; = \; 2.25 \times 10^{23}$$

2) number of Pb atoms

$$1.125 \times 10^{23} \text{ atoms}$$

3) mass of Pb

mass = R.A.M x number of moles

$$207.2 \times \left(1.125 \times 10^{23} \div 6.023 \times 10^{23}\right) = \boxed{38.7\text{g}}$$