- o 1. Element.
- o 2. Compound.
- o 3. Electrolysis.
- o 4. Chemical formula.
- o 5. Chemical equation.
- o 6. Law of Conservation of Mass.
- o 7. Temperature.
- o 8. Kinetic energy.
- o 9. Vaporization.
- o 10. Sublimation.
- o 11. Heating Curve of Water.

Matter

Is anything that has math and volume, it's made of atoms

Element -> a substance with the same type of atom, for **example** (H_2, O_3, S)

Compound -> a substance consisting of different atoms that are **chemically bonded**, for **example** (NaCl, H_2O)

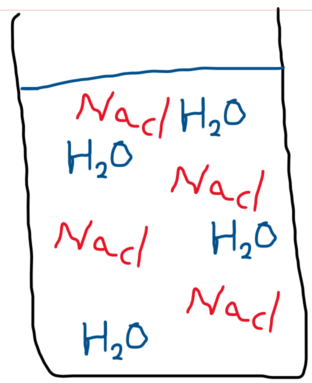
Molecule -> just multiple connected atoms, for **example** (H_2, NaCl)

Mixture -> the result of two or more **pure substances** that are **physically mixed** or can seperated with **physical means,** for **example** (salt water)

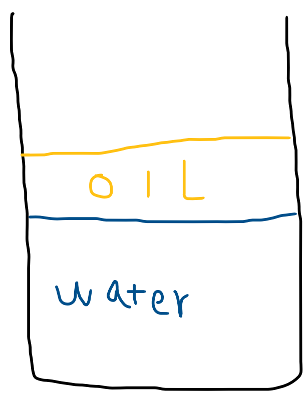
Commented [SD1]: As you can separate them physically by just boiling the water so it evaporates, and you'll be left with salt

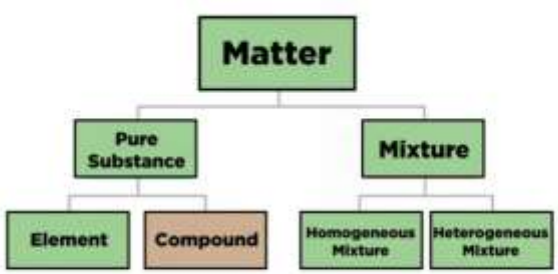
Mixtures have two types

Homogeneous mixtures -> it means that all substances in a mixture are distributed evenly and every section of it looks the same, **like salt or sugar water**, as it consits of two substances that can be split apart physically, but the mixture looks the same everywhere



Heterogeneous mixtures -> it means that the substances in a mixture are not distributed evenly and different sections look different and have a different amount of each substances, like **oil and water**





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LAW OF CONSERVATION OF MASS

It states that the mass before the reaction, **HAS** to be equal to the mass after the reaction

So let's say I have 2 atoms with each having the mass of 1

So the mass before the reaction is equal to **2**

Then the mass after the reaction **HAS** to be **2**

Because if it is less, then matter would've been erased

And matter can not be destroyed nor created

But sometimes, the mass might appear to change

Let's say you have the chemical reaction **Na + HCL => NaCl +** $\mathbf{H_2}$

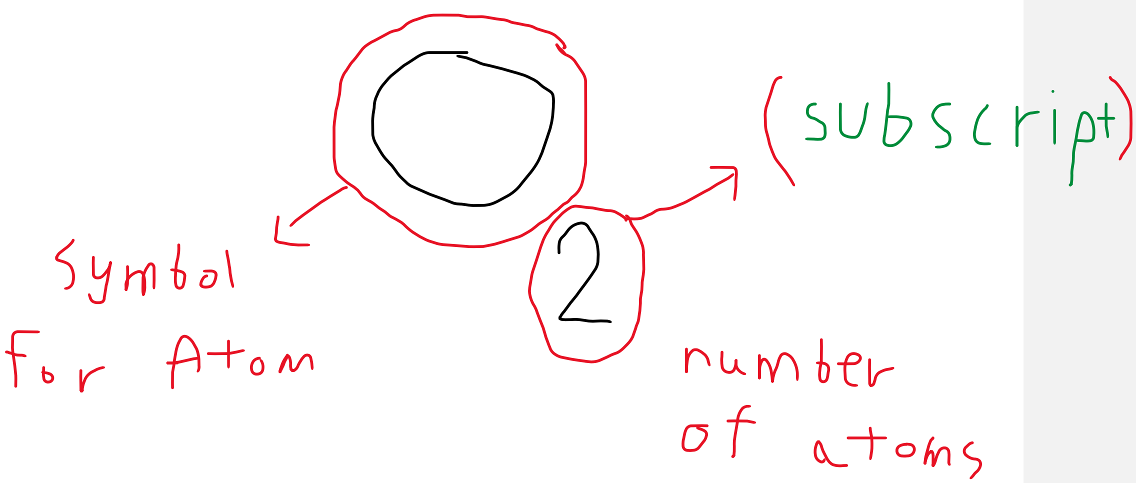
The product of this reaction might appear to have a **smaller mass** when you do them in open space, as the hydrogen is gas that can escape

But if you do it in a sealed container, the mass **wouldn't change**

CHEMICAL FORMULA

It's a short way to write what atoms are present in a chemical

So instead of saying "**one oxygen atom bonded to one oxygen atom**", you can just say $\mathbf{O_2}$



CHEMICAL EQUATION

It’s a symbolic representation of a chemical reaction, it consists of 3 main parts

Reactants -> Products

Commented [SD2]: This is called the reaction arrow, it tells us the direction of the chemical reaction, sometimes it might look double-headed like this **($\rightleftharpoons$)**, which tells us that this reaction can happen in both ways

EXAMPLE -> $2H_{2(l)}$ + $2O$ -> $2H_2O$

NOTE 1 -> The number highlighted in **red** is called a **coefficient**, it tells us the mole count of the matter, or if we went to small scale, a multiplier for the amount of atoms

Commented [SD3]: a mole is a unit used to measure the amount of a substance. One mole of a substance contains approximately **(6.022×10^{23})** elementary entities (such as atoms, molecules, ions, or particles). This number is known as Avogadro's number.

Basically in our context

2 moles of H_2 and 2 moles of oxygen will result in 2 moles of water molecules

NOTE 2 -> When you have a compound like **H_2O** or **$CaCO_3$**, don’t place the coefficient in front of each part of the equation like **$2H_22O$** or **$2Ca2CO_3$**
but just add one coefficient in front, so it will be **$2H_2O$** and **$2CaCO_3$**

NOTE 3 -> when you have a chemical equation like this $2Nacl_{(aq)}$ -> $2Na_{(s)}$ + $Cl_{2\ (g)}$
those symbols refer to the state of the substance in the reaction, here is a list of them

Commented [SD4]: S => Solid
G => Gas
L => liquid or molten/melted
Aq => Aqueous solution (dissolved in water)

BALANCING CHEMICAL EQUATIONS

To balance a chemical equation, the number of atoms on one side, must equal the number of atoms on the other side, you can do that by **changing the coefficient**, DO NOT change the subscript

So for example

$Fe + O_2$ -> Fe_2O_3

As you can see, there is a problem here

Reactant side => 1 iron, 2 oxygen | **Product side =>** 2 iron, 3 oxygen

We can fix it by adding coefficients/multipliers to each part of the equation

Here it is step by step

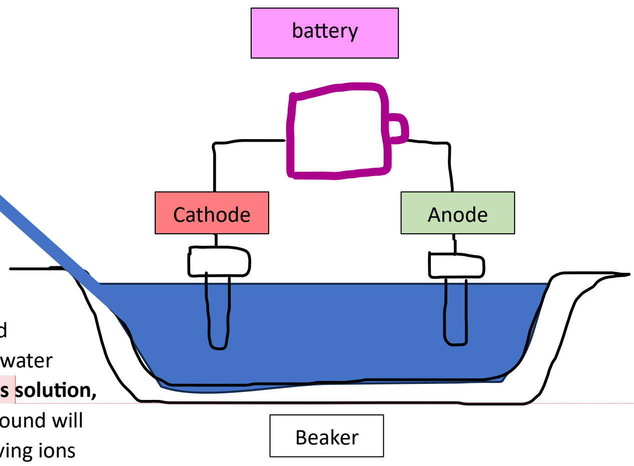
1. **Try to balance the number of iron atoms ->** we set the reactant **Fe** to have a coefficient of **2** so it becomes **$2Fe + O_2$ -> Fe_2O_3**
2. **Try to balance the number of oxygen atoms ->** you have 3 oxygen on the product side, and 2 oxygen on the reactant side, to make them equal, you must make them both into the same number, let’s say 6, so we make the coefficient of the reactant oxygen into **3**, and the coefficient of the product oxygen into **2**, so it becomes **$2Fe + 3O_2$ -> $2Fe_2O_3$**
3. **Try to balance the number of iron atoms again** -> because the product **Fe** shares the same coefficient as its O, then we now have 4 iron on the product side, and 2 iron on the reactant side, so we can just turn the coefficient on the reactant side to **4** instead of **2**, and we have this balanced equation **$4Fe + 3O_2$ -> $2Fe_2O_3$**

This is basically how balancing works, you just play around with the coefficients until the left side equals the right side

ELECTROLYSIS

It's splitting up ionic compounds with electricity

Every electrlysis experiment has the same main parts



THE ELECTROLYTE

It's the solution that has the ionic compound that you are going to split

It can be one of two things depending on the compound

- **IF IT IS SOLUBLE**
  - Then the compound will be dissolved in water creating an **aqueous solution,** that way the compound will split into freely moving ions across the water
- **IF IT IS INSOLUBLE**
  - Then the compound will be melted, that way the compound will split into freely moving ions

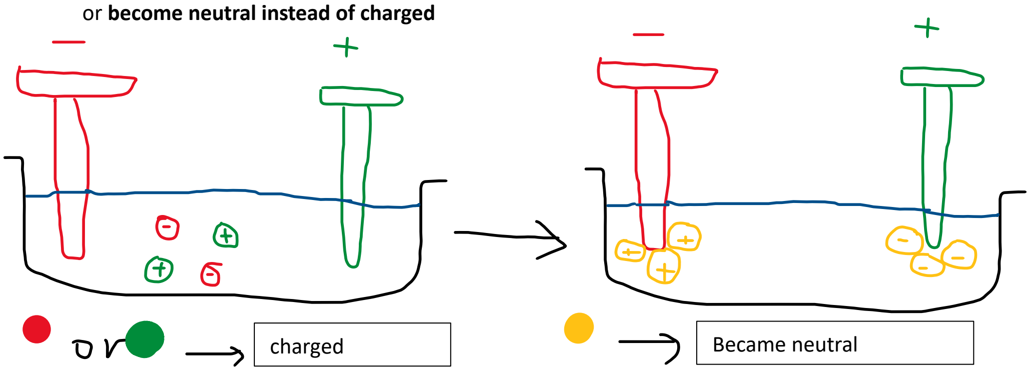
The reason we want freely moving ions, is that we need them to split a part, if they were bonded and not freely moving, the separating won't happen

How does electrolysis happen?

When an electric source is added like a battery, the cathode and anode become charged, the cathode is **negatively charged** and the anode is **positively charged**

the **positive ions** of the compound will **go** to the **negatively charged cathode** and they will be **discharged** or **become neutral instead of charged**

the **negatively ions** of the compound will **go** to the **positively charged anode** and they will be **discharged** or **become neutral instead of charged**



Commented [SD5]: Dissolved in water

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now the ions here are being **Oxidized** and **Reduced** to the electrodes

let's say we have **melted NaCl** as our ionic compound

the **chlorine negative ion** will be **oxidized** into normal chlorine, so the reaction will look like this

$$Cl^- \rightarrow Cl + e^-$$

So **oxidization** means losing electrons

the **sodium positive ion** will be **oxidized** into normal sodium, so the reaction will look like this

$$Na^+ + e^- \rightarrow Na$$

So **reduction** means gaining electrons

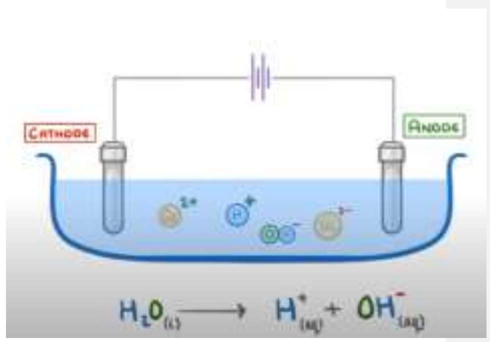
These two equations are **half-equations** for each part of the compound

The full equation for the NaCl ionic compound is written like this

$$NaCl_{(l)} \rightarrow Na_{(l)} + Cl_{(g)}$$

ELECTROLYSIS IN AQUEOUS SOLUTIONS

One of the hardest challenges in aqueous electrolysis is figuring out where ions go, let's imagine electrolysis in a **CuSO4 aqueous solution**, we would have positive copper ions and negative sulfate ions, but we will also have **positive hydrogen ions** and **negative hydroxide ions**

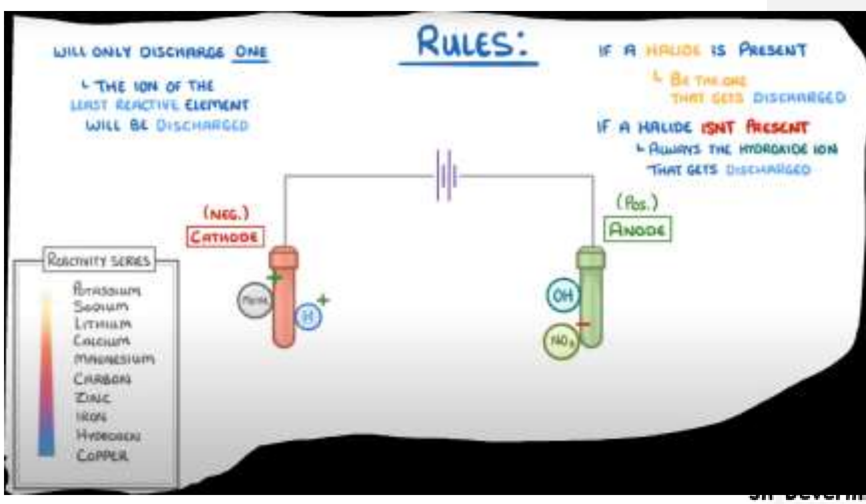


When the positive ions like **hydrogen** and **copper** go to the **cathode**, only 1 ion will be discharged

When the negative ions like **sulfate** and **hydroxide** go to the **anode**, only 1 ion will be discharged

To know who will be discharged, you need to know this

Halide means a compound that has group 17 in the periodic table, aka halogens like **Florine, chlorine, bromine, iodine**



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Going back to our CuSO4 EXAMPLE

In the cathode, the copper atom will be discharged as it's less reactive than the hydrogen

In the anode, the hydroxide always wins when there is no halides so it will be the one that gets discharged, the **neutral hydroxide** will then **go on to form water and oxygen**

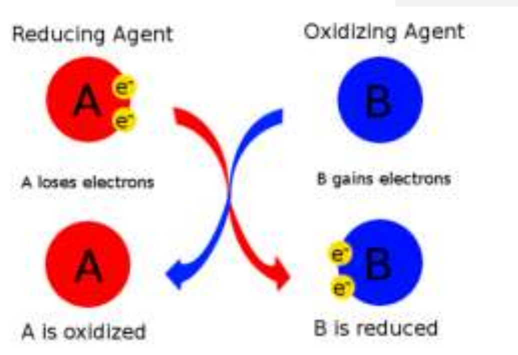
So we have a **neutral hydroxide** and a **neutral copper** atom, and a **sulfate ion** and a **hydrogen ion**

The equation for the hydroxide is

$$4OH^- \rightarrow 2H_2O + O_2 + 4e^-$$

so here is how ions are neutralized by the electrodes

- negative ions go to the positive electrode to lose the extra electrons in a process called **oxidization**
- positive ions go the negative electrode to gain the extra electrons in a process called **reduction**



now here is the tricky part

positive ions that go through **reduction** are called **oxidizing agents**

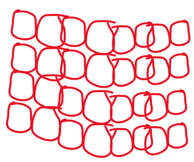
negative ions that go through **oxidization** are called **reducing agents**

STATES OF MATTER

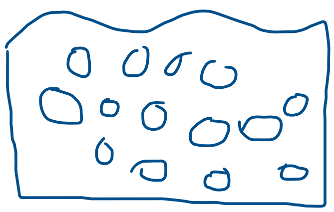
There are a lot of states, but we have 3 to learn right now

SOLIDS – LIQUIDS – GASES

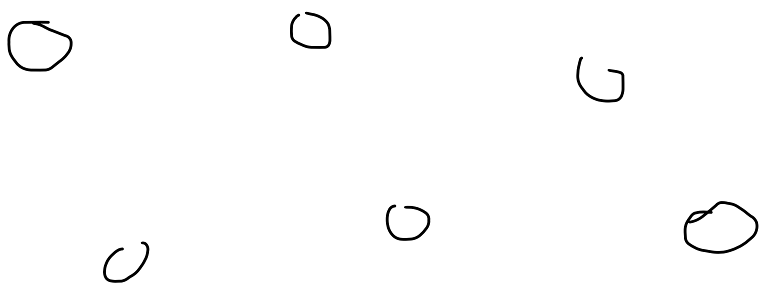
SOLIDS are when atoms are arranged and tightly packed together and have a specific definite shape



LIQUIDS are when atoms are not packed, they have the same volume, but take different shapes



GASES are when atoms are left unpacked, they have changing volumes and shapes



Matter can switch between these states through **phase transitions** (changing the **temperature**)

Temperature

Is the measure of the average kinetic energy of the particles in a substance, the more the kinetic energy, the higher the temperature, and opposite wise

Phase transitions

Melting -> solids turn into liquids when the temperature rises to the **melting point**

Freezing -> Liquids turn into solids when temperature cools down to the **freezing point**

Evaporation -> Liquids turn into gases **on the surface of the liquid**, and it occurs at any temperature, even if it's smaller than the boiling point, here is the reason for it

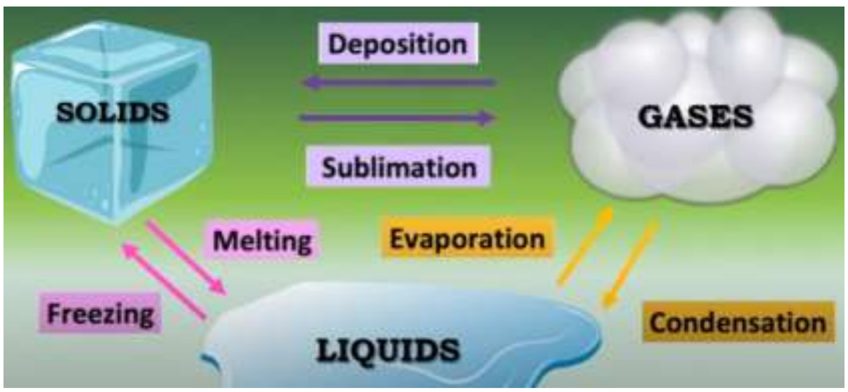
Commented [SD6]: Because the warmer air around the surface of the liquid, gives the liquid particles enough energy overtime to escape as gas (vapor)

Vaporization -> Liquids turn into gases **throughout the entire body of the liquid,** and it occurs at the **boiling point** of the liquid, and it occurs rapidly compared to evaporation as the whole body of liquid is getting converted

Condensation -> Gases turn into liquids when the temperature cools down

Sublimation -> Solids turn into gases when the temperature is so hot that It doesn't even bother going through the liquid phase

Deposition -> Gases turn into solids when the temperature is so cold that it doesn't even bother going through the liquid phase



Evaporation	Vaporisation
The process by which a liquid changes to its vapours at a temperature below its boiling point.	The process by which a liquid changes to its vapours at its boiling point.
Evaporation takes place at all temperatures. The temperature may change during evaporation.	Vaporisation takes place only at a fixed temperature called the boiling point of the liquid. The temperature during vaporisation does not change.
Evaporation is a slow and silent process.	Vaporisation is a fast and violent process.
Evaporation takes place only at the surface of the liquid.	Vaporisation takes place over the entire mass of the liquid.
The rate of evaporation depends upon the surface area of the liquid and wind speed, humidity and temperature.	The rate of vaporisation does not depend upon the surface area, wind speed, humidity and temperature.

KINETIC ENERGY

It's the energy of motion of an object

In the macro/big scale, it is calculated like this $\mathbf{K_e = \frac{1}{2}MV^2}$

But in the **microscale,** it's calculated like this

FOR PARTICLES

$$\textit{Kinetic energy} = \frac{3}{2}kt$$

Where

- **k =** Boltzmann's constant **(1.38 x 10^{-23} Joules/Kelvin)**
- **t =** temperature in kelvin

NOTE:

The average velocity of the particle is $v_{Rms} = \sqrt{\frac{3kt}{m}}$

Where v_{Rms} : is the root mean square (AKA average velocity).

k : is the Boltzmann's constant.

t : is the temperature.

m : is the mass of the molecule.

Proof:

- $\frac{3}{2}kt = \frac{1}{2}mv^2$
- $v_{Rms} = \sqrt{\frac{3kt}{m}}$, $v^2 = \frac{3kt}{m}$
- $\frac{1}{2} x\ m\ x\ \frac{3kt}{m}$
- $\frac{1}{2} x\ m\ x\ \frac{3kt}{m}$
- $\frac{3}{2}kt$

Figure 1to be honest, i don't know what that me

So to get the velocity, just reverse the law $\mathbf{K_e = \frac{1}{2} MV^2}$ and replace $\mathbf{K_e}$ with the **3/2 kt**

FOR MOLES

$$\textit{Kinetic energy} = \frac{3}{2}Rt$$

Where

- **R =** the gas constant (**8.314 J / mol . k)**
  - Here
    mol = mole, and a single mole is equal to **6.022x10^{23}** atoms **(Avogadro's number)**
    k = temperature in kelvin
- **t =** temperature in kelvin

here, the root mean square velocity $\mathbf{V_{Rms}} = \sqrt{\frac{3Rt}{m}}$

where

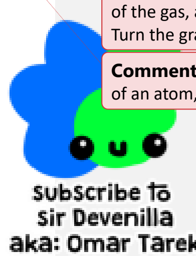
- R = gas constant
- T = temperature in kelvin
- M = **molar mass in KG**

Commented [SD7]: temperature unit conversion:
• Celsius to Kelvin: K = °C + 273.15
• Kelvin to Celsius: °C = K - 273.15
• Celsius to Fahrenheit: °F = (°C * 9/5) + 32
• Fahrenheit to Celsius: °C = (°F - 32) * 5/9
• Kelvin to Fahrenheit: °F = ((K - 273.15) * 9/5) + 32
• Fahrenheit to Kelvin: K = ((°F - 32) * 5/9) + 273.15

Commented [SD8]: Do not replace anything in the gas constant, these are just معلومات عامه

Commented [SD9]: You get it by taking the atomic mass of the gas, and making it into grams**, IN OUR CASE** Turn the grams into kilograms

Commented [SD10]: If you don't know the atomic mass of an atom, just take its mass number as the atomic mass



What is the root mean square velocity (v_{Rms}) of a sample of helium gas at 400 k

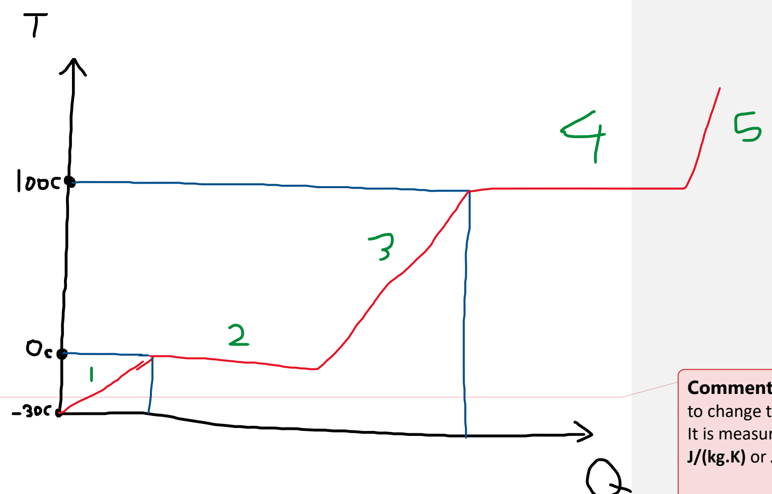
1- Get the molar mass in KG
   a. The atomic mass of helium is **4u, then the molar mass is 4 grams**
   b. Turn the molar mass into KG => 4 * 10^{-3} = 4x10^{-3} KG
2- Use the law **V_{Rms} =** $\sqrt{\frac{3Rt}{m}}$
3- **V_{Rms} =** $\sqrt{\frac{3 \times 8.314 \times 400}{4 \times 10^{-3}}}$ **= 1579.3 ~ 1580 m/s**

HEATING CURVE FOR WATER

Let's imagine a graph where the

- **X axis ->** amount of heat energy added
- **Y axis ->** temperature in Celcius

Let's start with **ice at 30° celcius** and heat it



There are 5 points of interest here

1. We are heating **ice**, the amount of gained heat energy (**Q**) can be calculated using this equation
   $$Q = mc\Delta T$$
   a. m => mass of the sample (aka ice)
   b. c => the specific heat capacity
   c. ΔT => change in temperature

   Also, when you're increasing the heat, you're increasing the temperature, **therefore,** you're increasing the kinetic energy of the ice
2. Here, a phase change is occurring from **solid** to **liquid,** to calculate the amount of gained heat energy (Q), you use this equation
   $$Q = n\Delta H_{fusion}$$
   where
   a. N => number of moles in a substance
   b. The molar enthalpy of fusion

Commented [SD11]: Unit for measuring the atomic mass

Commented [SD12]: It's going to be symbolized as **Q** with the unit being **joules**

Commented [SD13]: The amount of heat energy required to change the temperature of a unit of mass of a substance
It is measured in
J/(kg.K) or **J/(g.°C)**

Water has a specific heat capacity of about **4.18 J/(g·°C) or 4.18 J/(g·K),** which means it takes **4.18 joules** of energy to **raise the temperature of 1 gram of water by 1 degree Celsius.**

Commented [SD14]: also known as the heat of fusion, is the amount of heat energy required to change one mole of a substance from its solid state to its liquid state at its melting point, while keeping the temperature constant.
It's measured in kilojoules for mole **kJ/mol**
for water, the molar enthalpy of fusion is approximately 6.01 kJ/mol. This means it takes 6.01 kilojoules of heat energy to change one mole of ice at its melting point (0°C or 273.15 K) into liquid water at the same temperature without changing its temperature.

3. We are heating **water**, the amount of gained heat energy (**Q**) can be calculated using this equation

$$\boldsymbol{Q = mc\Delta T}$$

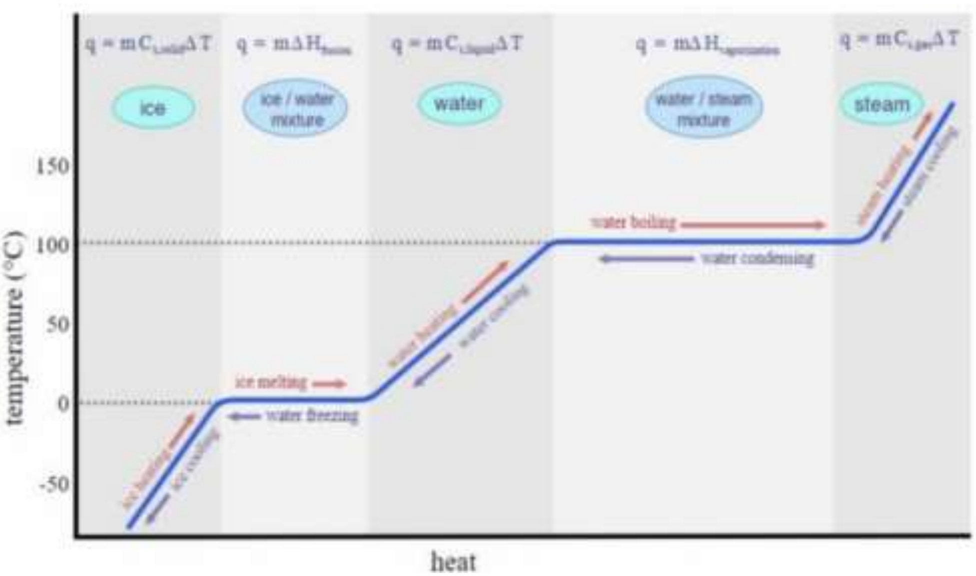
   a. m => mass of the sample (aka liquid water)
   b. c => the specific heat capacity
   c. ΔT => change in temperature
4. Here, a phase change is occurring from **liquid** to **gas,** to calculate the amount of gained heat energy (Q), you use this equation

$$Q = n\Delta H_{vaporization}$$

   where
   a. N => number of moles in a substance
   b. The molar enthalpy of fusion
5. We are heating **steam**, the amount of gained heat energy (**Q**) can be calculated using this equation

$$\boldsymbol{Q = mc\Delta T}$$

   a. m => mass of the sample (aka steam)
   b. c => the specific heat capacity
   c. ΔT => change in temperature



Commented [SD15]: The amount of heat energy required to change the temperature of a unit of mass of a substance
It is measured in
J/(kg.K) or **J/(g.ºC)**

Water has a specific heat capacity of about **4.18 J/(g·°C) or 4.18 J/(g·K),** which means it takes **4.18 joules** of energy to **raise the temperature of 1 gram of water by 1 degree Celsius.**

Commented [SD16]: also known as the heat of fusion, is the amount of heat energy required to change one mole of a substance from its solid state to its liquid state at its melting point, while keeping the temperature constant.
It's measured in kilojoules for mole **kJ/mol**
for water, the molar enthalpy of fusion is approximately 6.01 kJ/mol. This means it takes 6.01 kilojoules of heat energy to change one mole of ice at its melting point (0°C or 273.15 K) into liquid water at the same temperature without changing its temperature.

Commented [SD17]: The amount of heat energy required to change the temperature of a unit of mass of a substance
It is measured in
J/(kg.K) or **J/(g.ºC)**

Water has a specific heat capacity of about **4.18 J/(g·°C) or 4.18 J/(g·K),** which means it takes **4.18 joules** of energy to **raise the temperature of 1 gram of water by 1 degree Celsius.**

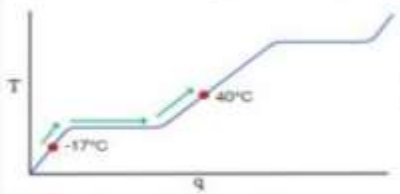
HOW GET THE NET HEAT ENERGY

X

Step 1: Change temperture units to Celcius.

°C = (°F - 32)/1.8 which means that 0 °F = -17 °C and 104 °F = 40 °C

Step 2: Map out the regions and temperatures on the heating curve. This is your "map" for the problem.



Note that there are 3 regions to calculate heat. They are
1) heating the -17 °C ice to 0 °C ice
2) melting the 0 °C ice to 0 °C water
3) heating the 0 °C water to 40 °C water

Step 3: do the calculations for each step

$q_1 = m\ C_{s,ice}\ \Delta T_{ice}$ = (125 g ice)(2.09 J/g°C)(17°C) = 4441 J

$q_2 = m\ \Delta H_{fusion}$ = (125 g ice)(334 J/g) = 41750 J

$q_3 = m\ C_{s,water}\ \Delta T_{water}$ = (125 g ice)(4.184 J/g°C)(40°C) = 20920 J

Step 4: Sum the steps and convert to kJ

4441 + 41750 + 20920 = 67111 J = **67.1 kJ**

Traversing the Curve

A full blown "heating curve" question will generally cover more that one region on the curve above. So what you have to realize is that you will break the problem into the regions as described and calculate the heats (q's) for each region. You then sum up the heats for each of the regions in the problem. More complicated problems will envolve the possibility of two samples starting at two different parts of the curve, but ultimately reaching the same exact final point (temperature and composition). Examples follow.

Those values for water are the following:

$C_{s,ice}$ = 2.09 J/g °C

$C_{s,water}$ = 4.184 J/g °C

$C_{s,steam}$ = 2.03 J/g °C

ΔH_{fusion} = 334 J/g

$\Delta H_{vaporization}$ = 2260 J/g

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