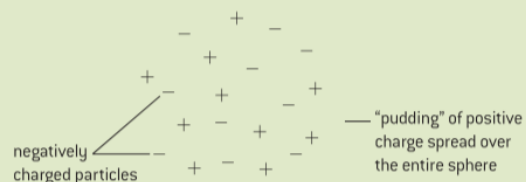


## Particulate Nature of Matter (1) - Guided Notes

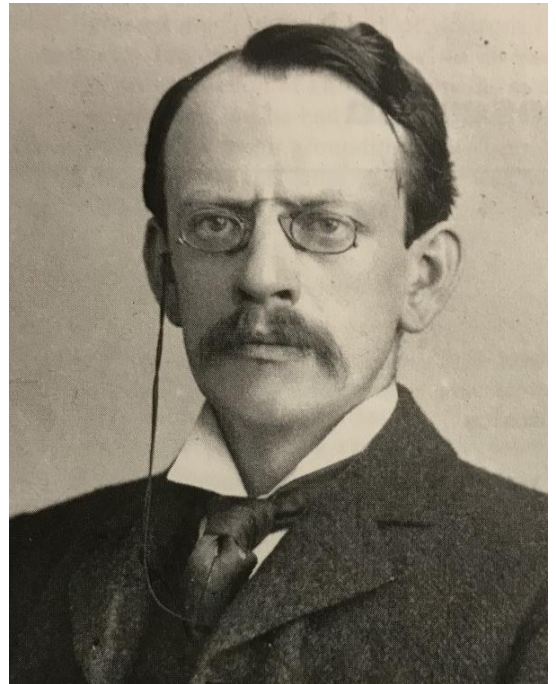
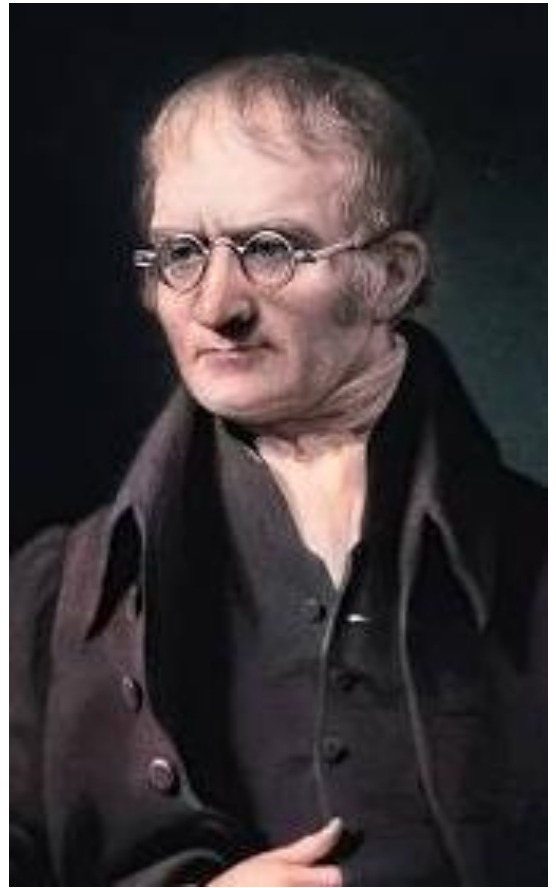
### Slide 3: Model of the Atom

- Dalton (1808)
- Thomson (1904)

- *Postulate 1:* All matter (materials) consists of very small particles called **atoms**.
- *Postulate 2:* An **element** consists of atoms of one type only.
- *Postulate 3:* **Compounds** consist of atoms of more than one element and are formed by combining atoms in whole-number ratios.
- *Postulate 4:* In a chemical reaction atoms are not created or destroyed.

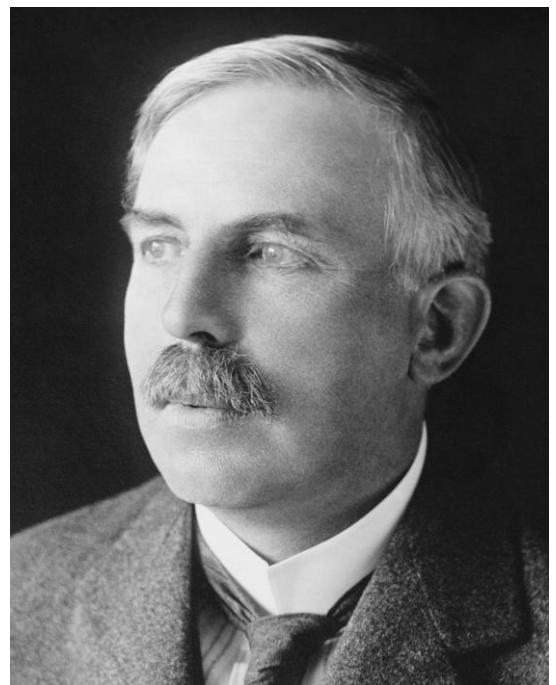
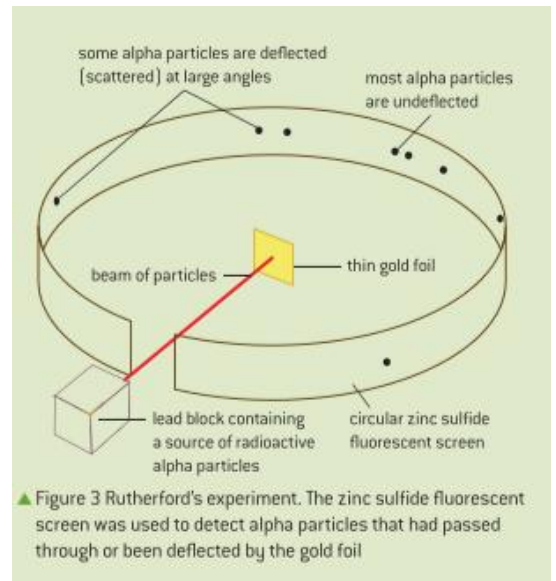


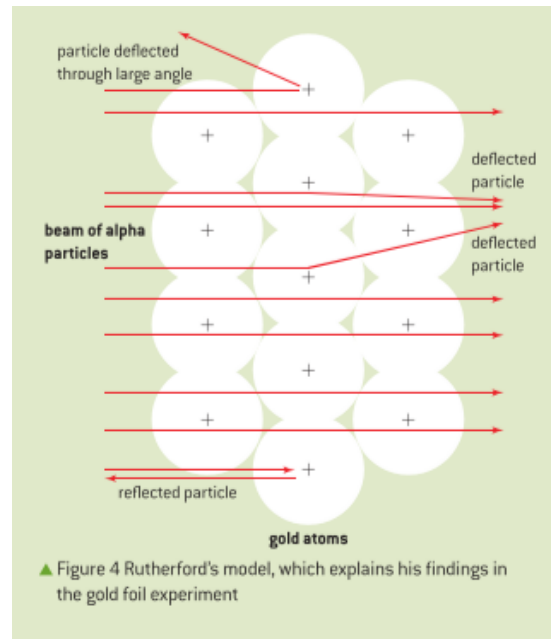
▲ Figure 2 Thomson's "plum-pudding" model of the atom. In the analogy, raisins represent negatively charged particles embedded in a pudding of positive charge. Overall there is a balance between the positive and negative charges since the atom is electrically neutral



#### Slide 4: Model of the Atom

- Rutherford (1911)





## Slide 5: Subatomic Particles

- James Chadwick \_\_\_\_\_ the neutron in 1932

$$1 \text{ amu} = 1.660539 \times 10^{-24} \text{ g}$$

Subatomic particle	Charge	Mass/amu	Location
proton	+1	~ 1	nucleus
neutron	0	~ 1	nucleus
electron	-1	$\frac{1}{1836}$	outside the nucleus in the electron cloud

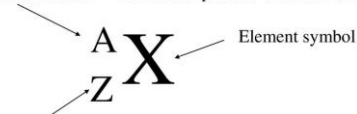
▲ Table 1 A comparison of the subatomic particles



## Slide 6: Nuclear Symbol

- Protons and \_\_\_\_\_ can be called Nucleons

Mass number = number of protons + number of neutrons



Atomic number = number of protons

$A$  = number of protons + number of neutrons

$Z$  = number of protons

$A - Z$  = number of neutrons

**\*\*Number of neutrons = Mass Number - Atomic Number\*\***

## Slide 7: Examples

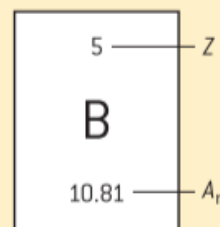


## Slide 8: TIP!

- Don't confuse the nuclear symbol with an element's \_\_\_\_\_ on the periodic table.
- The nuclear symbol refers to an isotope (aka nuclide) and \_\_\_\_\_ the atomic number ( $Z$ ) and mass number ( $A$ ).
- On the \_\_\_\_\_ table, the atomic number ( $Z$ ) and the relative atomic mass ( $A_r$ ) is given.
- The ratio of the \_\_\_\_\_ **mass** of an atom to the unified atomic mass unit.

### Study tips

In the periodic table of elements in section 6 of the *Data booklet*, the atomic number  $Z$  is given above the symbol for each element. The number below the symbol represents the relative atomic mass,  $A_r$  (figure 12).



▲ Figure 12 Periodic table entry for boron

## Slide 9: Isotopes

- \_\_\_\_\_ forms of the same element that have the same number of protons (Z) but different mass numbers (A) because they have different numbers of neutrons.
- Most \_\_\_\_\_ exist as mixtures of isotopes.
- Isotopes have the same chemical \_\_\_\_\_ (same number of protons) but different physical properties (different mass numbers)
- **U-235 is used in nuclear reactors and weapons. However, natural uranium ore has more U-238, so is enriched to increase levels of U-235 (isotope \_\_\_\_\_).**

### isotope enrichment: Nuclear energy and nuclear weapons

Uranium found in nature consists of three isotopes with the relative abundances and atomic compositions shown in table 2.

Isotope	Relative abundance	Number of protons	Number of electrons	Number of neutrons
<sup>234</sup> U	0.0055%	92 protons	92 electrons	142 neutrons
<sup>235</sup> U	0.7200%	92 protons	92 electrons	143 neutrons
<sup>238</sup> U	99.2745%	92 protons	92 electrons	146 neutrons

▲ Table 2 Isotopes of uranium

Uranium-235 is used in nuclear reactors where it undergoes **fission** (splitting) with the release of a large amount of energy. Natural uranium has a much higher abundance of U-238 than U-235 so uranium ore may be **enriched** to increase the proportion of U-235. The separation of natural uranium into enriched uranium and depleted uranium is the physical process of **isotope separation**.

## Slide 10: Relative Atomic Mass

- The ratio of the \_\_\_\_\_ **mass** of an atom to the **unified atomic mass unit**.
- The mass of an atom is \_\_\_\_\_ by the number of protons and neutrons (electron mass is negligible).
- Since atomic masses are so small, it is more \_\_\_\_\_ to use *relative atomic masses* ( $A_r$ ).
- 1/12 the size of a carbon-12 atom.
- 1 amu (1u) =  $1.66005402 \times 10^{-27}$  kg
- \_\_\_\_\_ **atomic masses are ratios, so do not include units!**
- **When using \_\_\_\_\_ atomic masses from the Data Booklet, always express values to 2 decimal places.**

## Slide 11: How to Find the Relative Atomic Mass

Boron has two naturally occurring isotopes with the natural abundances shown in table 3.

Isotope	Natural abundance/%
<sup>10</sup> B	19.9
<sup>11</sup> B	80.1

▲ Table 3 Isotopes of boron

Calculate the relative atomic mass of boron.

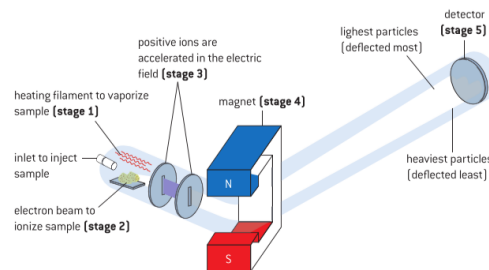
### Solution

The relative atomic mass is the weighted average of the atomic masses of the isotopes and their relative abundance:

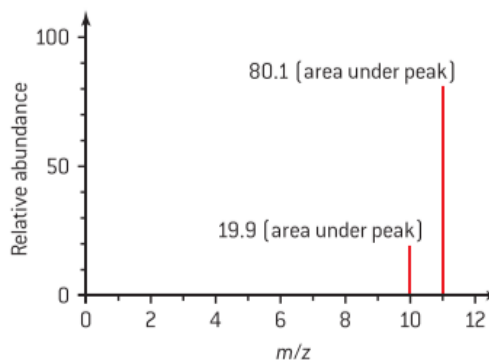
$$\text{relative atomic mass} = \left(10 \times \frac{19.9}{100}\right) + \left(11 \times \frac{80.1}{100}\right) = 10.8$$

## Slide 12: Measuring Atomic Mass/Isotopic Composition

- **Mass \_\_\_\_\_**: tool that ionizes particles and separates them based on their mass/charge ratio.
- **The height of each peak \_\_\_\_\_ to the relative abundance of each isotope.**



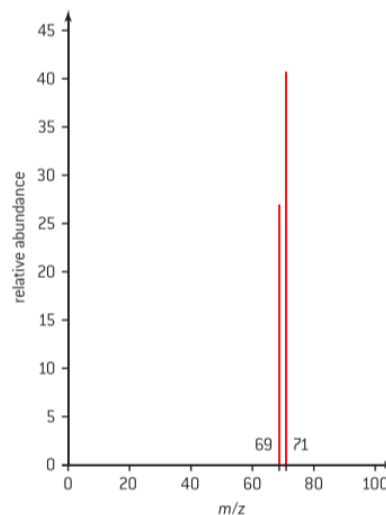
▲ Figure 10 Schematic diagram of a mass spectrometer



▲ Figure 11 Mass spectrum of boron. The two peaks correspond to two isotopes

## Slide 13: Measuring Relative Atomic Mass from Spectrometry

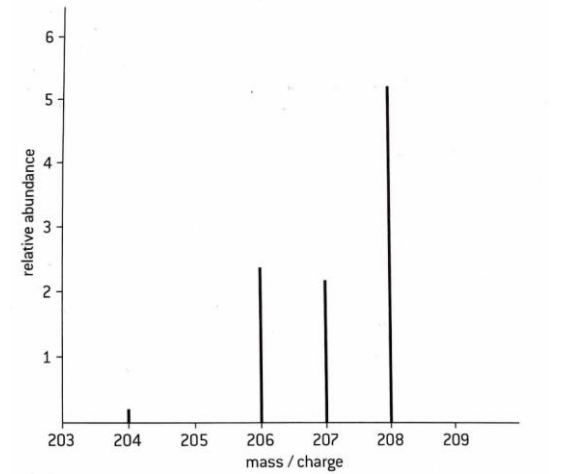
- Deduce the relative atomic mass of the element X from its mass spectrum and identify X from the periodic table.
- Total area of peak heights: 27 + 41 = 68
- **Calculate relative abundance of each isotope:**
- X-69:  $(27/68) \times 100 = 40\%$
- X-71:  $(41/68) \times 100 = 60\%$
- **Relative atomic mass:**
- $0.40 (69) + [0.60 (71)] = 70.2 \approx 70$  (2 sig figs)
- X is Gallium (Ga)
- Peak height: 27
- Peak height: 41
- **When doing mathematical calculations to solve for relative atomic use, use the appropriate number of sig. figs. as determined by the problem.**



▲ Figure 13 Mass spectrum of X showing the relative abundances of its naturally occurring isotopes

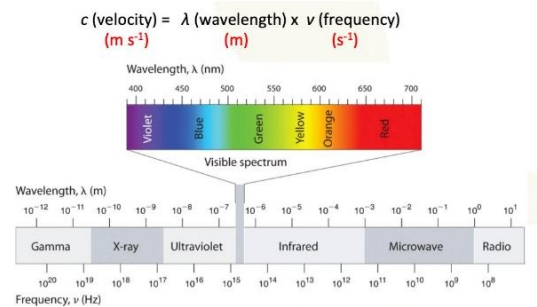
### Slide 14: You Try!

- Deduce the relative atomic mass of the element X from its mass spectrum and identify X from the periodic table.
- 0.2
- 2.4
- 2.2
- 5.2



### Slide 15: The Electromagnetic Spectrum

- \_\_\_\_\_ 3 of the data booklet
- High energy
- High frequency
- Short wavelength
- Low energy
- Low frequency
- Long wavelength



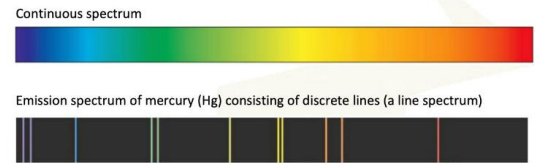
Slide 16: When electrons gain energy, they become excited and move to higher energy levels

Electrons emit energy when they drop back down to lower levels.

Each element produces a unique emission spectrum.

Emission spectra are not continuous (have discrete lines at particular wavelengths)

- Emission Spectra
- Lines represent \_\_\_\_\_ between energy levels

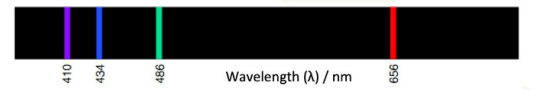


Slide 17: Hydrogen produces other emission spectra that can't be seen with the naked eye (UV or infrared)

All spectra have discrete lines that converge towards the high energy end of the spectrum

Provide evidence that the electron in hydrogen can only exist in certain fixed energy levels.

- \_\_\_\_\_ Emission Spectrum

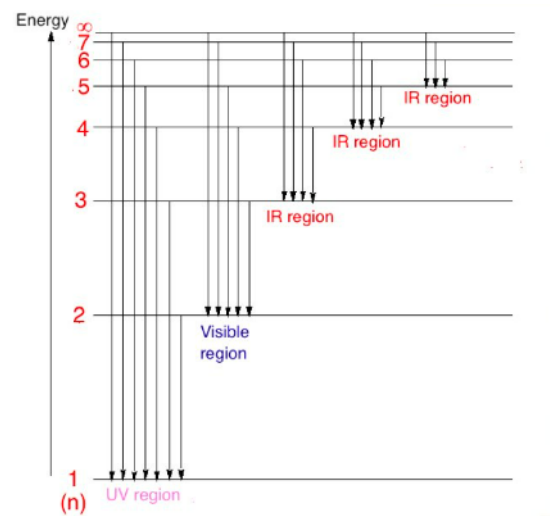


Slide 18: n is the principal quantum number (indicates the energy level/size of orbital)

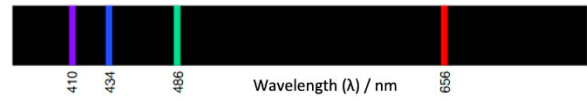
The visible emission spectrum of hydrogen is due to electrons falling to the n=2 level from higher levels.

As the value of n increases, the energy levels get closer together, causing the lines in the spectrum to converge.

- \_\_\_\_\_ Emission Spectrum
- $n = 3$        $n = 2$     656 nm
- $n = 4$        $n = 2$     486 nm
- $n = 5$        $n = 2$     434 nm
- $n = 6$        $n = 2$     410 nm



Slide 19: Balmer series



## Slide 20: Bohr's Planetary Model

- Designed a \_\_\_\_\_ atomic model that explained the line spectra of different elements
- \_\_\_\_\_ electrons existed at certain **energy levels** around the nucleus (called **principal energy levels**).
- \_\_\_\_\_ **farther away from the**
- \_\_\_\_\_ **are at higher energy levels**
- Bohr's model says that \_\_\_\_\_ orbit the nucleus at their lowest possible energy levels, but when the electrons absorb energy, they become excited and "jump" to the next highest energy levels. There is no stopping between levels.
- Energy levels are **quantized** (emissions of energy only occur in specific amounts/\_\_\_\_\_)
- [https://www.\\_\\_\\_\\_\\_.org/science/physics/quantum-physics/atoms-and-electrons/a/bohrs-model-of-hydrogen](https://www._____.org/science/physics/quantum-physics/atoms-and-electrons/a/bohrs-model-of-hydrogen)

## Slide 21: Quantum Model (of the Atom)

- The most recent and accurate model of the atom to date, in which there are seven principal energy levels and four sublevels \_\_\_\_\_ the nucleus, which describe the most likely location and position of an electron

## Slide 22: Electron Orbitals

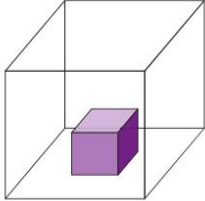
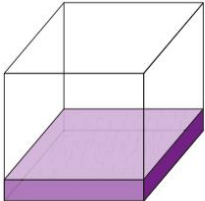
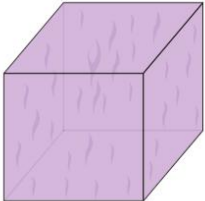
- The specific regions around the nucleus of an atom in which \_\_\_\_\_ travel

## Slide 23: De Broglie's hypothesis/The Quantum model

- Bohr's model was not accurate for elements with more electrons. Why? Bohr's model assumed electrons only acted as particles.
- Light has wave properties and consists of particles called photons (massless).
- In the 1920's, Louis de Broglie (French physicist) hypothesized that since waves behave like particles, then particles could behave like waves.
- **de Broglie's hypothesis: all forms of matter act like waves**
- **Electrons have wave-particle duality (they are particles AND waves).**

- [http://dev.physicslab.org/Document.aspx?doctype=3&filename=AtomicNuclear\\_deBroglieMatterWaves.xml](http://dev.physicslab.org/Document.aspx?doctype=3&filename=AtomicNuclear_deBroglieMatterWaves.xml)
- <https://physicstoday.scitation.org/doi/10.1063/pt.6.6.20180815a/full/>
- **Heisenberg Uncertainty Principle: It is impossible to know both the energy/momentum AND the exact position of an electron at the same time.**
- This is because when you try to find out the location of an electron through collisions, its speed and location will change.
- Led to electron orbits being replaced by **orbitals (probabilities of electron locations)**.
- <https://blog.thingswedontknow.com/2015/02/how-big-are-atoms.html>
- In 1926, Austrian physicist Erwin Schrodinger used this hypothesis to come up with and solve the Schrodinger equation, which led to the quantum mechanical model of the atom.

## Slide 24: Three States of Matter

Solid	Liquid	Gas
		
<ul style="list-style-type: none"> <li>• fixed volume</li> <li>• fixed shape</li> <li>• cannot be compressed</li> <li>• attractive forces between particles hold the particles in a close-packed arrangement</li> <li>• particles vibrate in fixed positions</li> </ul>	<ul style="list-style-type: none"> <li>• fixed volume</li> <li>• no fixed shape – takes the shape of the container it occupies</li> <li>• cannot be compressed</li> <li>• forces between particles are weaker than in solids</li> <li>• particles vibrate, rotate, and translate (move around)</li> </ul>	<ul style="list-style-type: none"> <li>• no fixed volume</li> <li>• no fixed shape – expands to occupy the space available</li> <li>• can be compressed</li> <li>• forces between particles are taken as zero</li> <li>• particles vibrate, rotate, and translate faster than in a liquid</li> </ul>

## Slide 25: Temperature

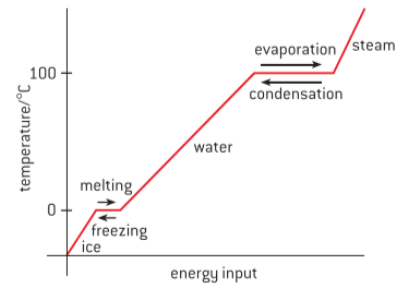
- **Average kinetic energy of \_\_\_\_\_**
- **Affects the way \_\_\_\_\_ move**
- SI unit of \_\_\_\_\_ is Kelvin (K)
- $K = ^\circ C + 273.15$

## Slide 26: Changes of State

- As a sample of ice at  $10\ ^\circ C$  is heated, the water \_\_\_\_\_ begin

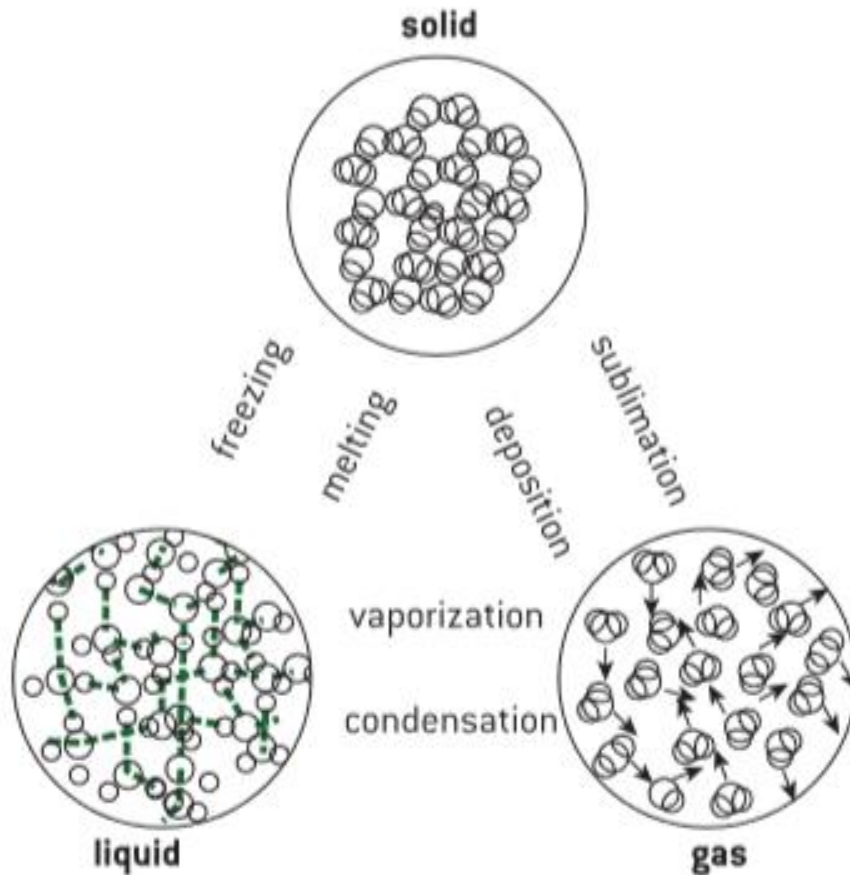
to vibrate more.

- At 0 °C, a solid-liquid \_\_\_\_\_ is reached. There is no change in temperature while melting is occurring (all energy is used to disrupt the crystal lattice and break attractive forces between molecules).
- After melting, the \_\_\_\_\_ vibrate faster and have more freedom of movement.
- Water starts to boil at 100 °C, where a liquid-gas \_\_\_\_\_ is reached (no temperature change occurs).
- After all liquid is converted to steam, the \_\_\_\_\_ can continue to rise.
- **equilibrium**
- **equilibrium**
- Melting and boiling are \_\_\_\_\_ reactions
- Freezing and \_\_\_\_\_ are **exothermic reactions**



▲ Figure 2 The heating curve for water

### Slide 27: Changes of State



▲ Figure 3 Changes of state for water

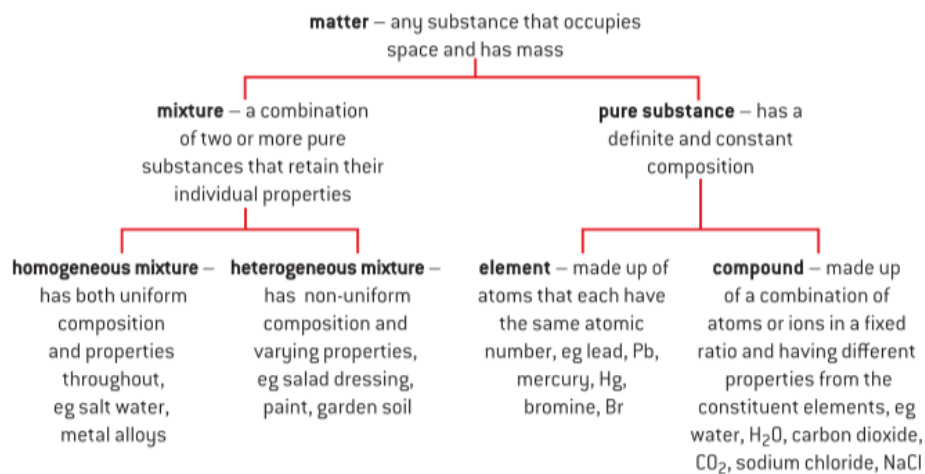
### Slide 28: Turn and Talk

- Why doesn't the temperature of a boiling liquid increase despite energy being constantly applied?

### Slide 29: Let's Practice!

- a) Deduce the number of protons, electrons, and neutrons in the isotopes  ${}_{17}^{37}\text{Cl}$  and  ${}_{17}^{35}\text{Cl}$ .
- b) Deduce the number of protons, electrons, and neutrons in the ion,  ${}_{17}^{37}\text{Cl}^{-}$ .

### Slide 30: Classification of Matter



▲ Figure 9 Elements, compounds, and mixtures

### Slide 31: Turn and Talk

- Research one additional application of \_\_\_\_\_ in modern society.

### Slide 32: You try!

Rubidium has a relative atomic mass of 85.47 and consists of two naturally occurring isotopes,  $^{85}\text{Rb}$  ( $u = 84.91$ ) and  $^{87}\text{Rb}$  ( $u = 86.91$ ). Calculate the percentage composition of these isotopes in a naturally occurring sample of rubidium.

### Slide 33: PhET Simulator

- [http://phet.colorado.edu/sims/html/rutherford-scattering/latest/rutherford-scattering\\_en.html](http://phet.colorado.edu/sims/html/rutherford-scattering/latest/rutherford-scattering_en.html)
- What does the simulation of the Rutherford model show?
- How does changing the atom size affect the scattering of the alpha particles?
- How does the results of the Rutherford simulation compare to that of the simulation of Thomson's model?