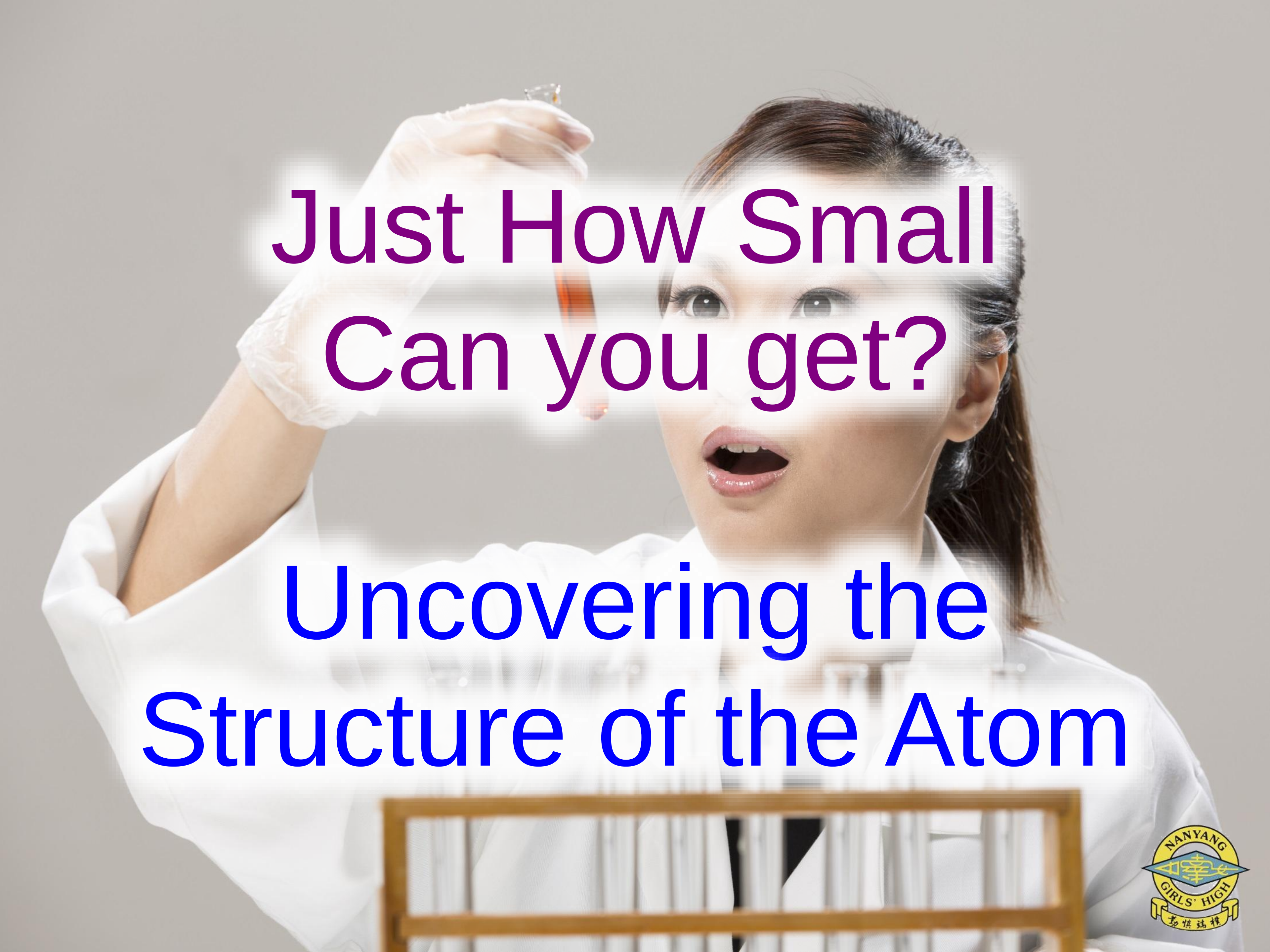

NANYANG
GIRLS' HIGH


Chemistry



Just How Small Can you get?

Uncovering the Structure of the Atom

Introduction to Atomic Structure – Models

What is today's lesson about?

- The structure of the *atom*.
- The nature of *scientific inquiry*. How do scientists think?
- How do scientists use *models* to help them understand complex scientific concepts?

Introduction to Atomic Structure – Models

What will we do in today's lesson?

- Reaction of sodium with water.
- Introduction to the atom.
- Presentation on atomic structure.
- Learn with interactive animations.
- Check your understanding through an online quiz.

Introduction to Atomic Structure – Models

What is an *atom* ?

- Watch the reaction between sodium and water.
- How small could you cut the piece of sodium and still get the same reaction to occur?

Introduction to Atomic Structure – Models

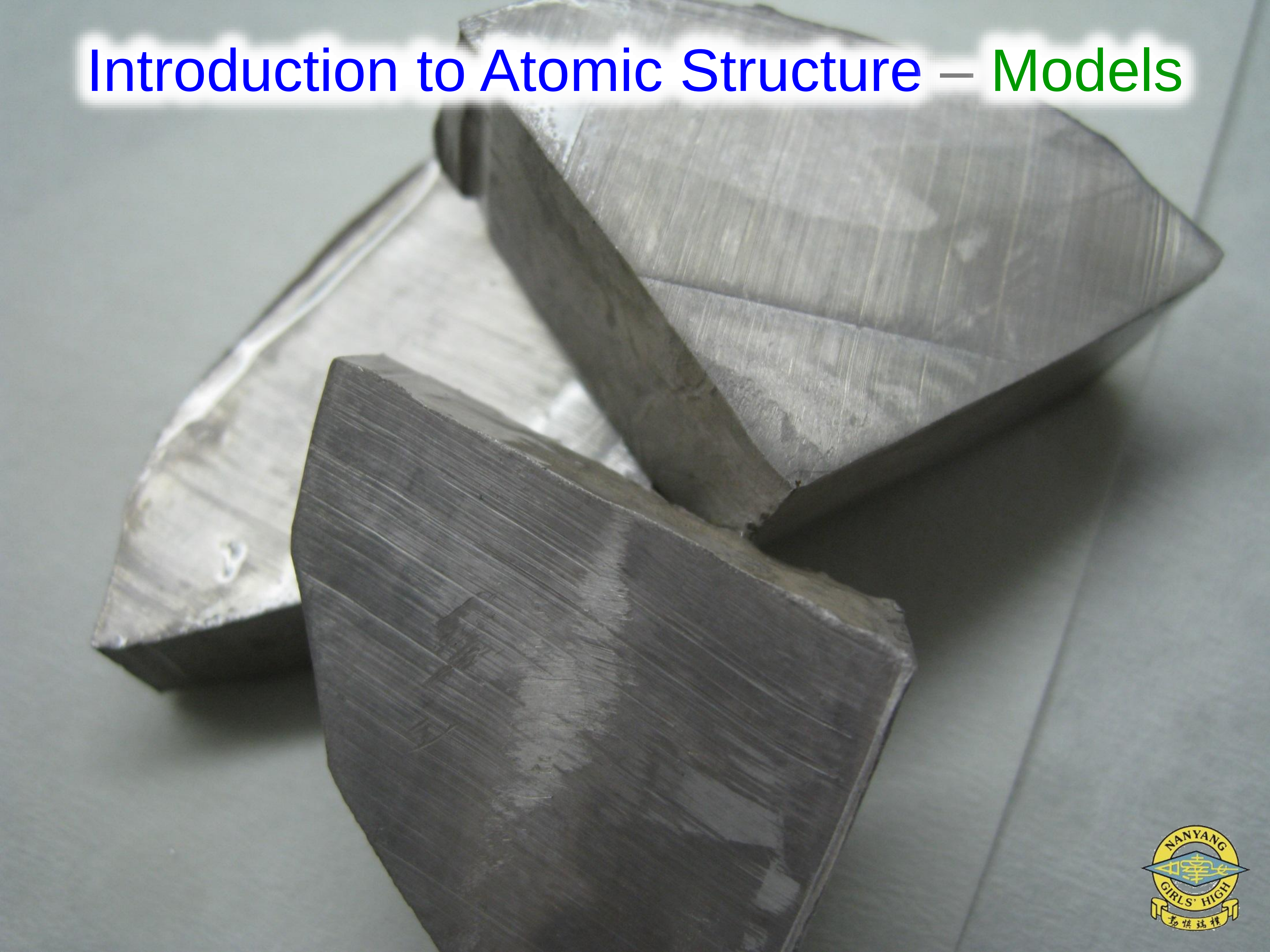
- The reaction of sodium and water.

- Time: 11 seconds.

sodium + water → sodium hydroxide + hydrogen

$2Na\ (s) + 2H_2O\ (l) \rightarrow 2NaOH\ (aq) + H_2\ (g)$

Introduction to Atomic Structure – Models



Introduction to Atomic Structure – Models

- How small could you cut the piece of sodium and still get the same reaction to occur?

Introduction to Atomic Structure – Models

- The smallest piece of sodium that would react with water in the same way as a lump of sodium is a *sodium atom*.
- An *atom* is the smallest part of a chemical element that demonstrates all of the typical chemical properties of that element.

Introduction to Atomic Structure – Models

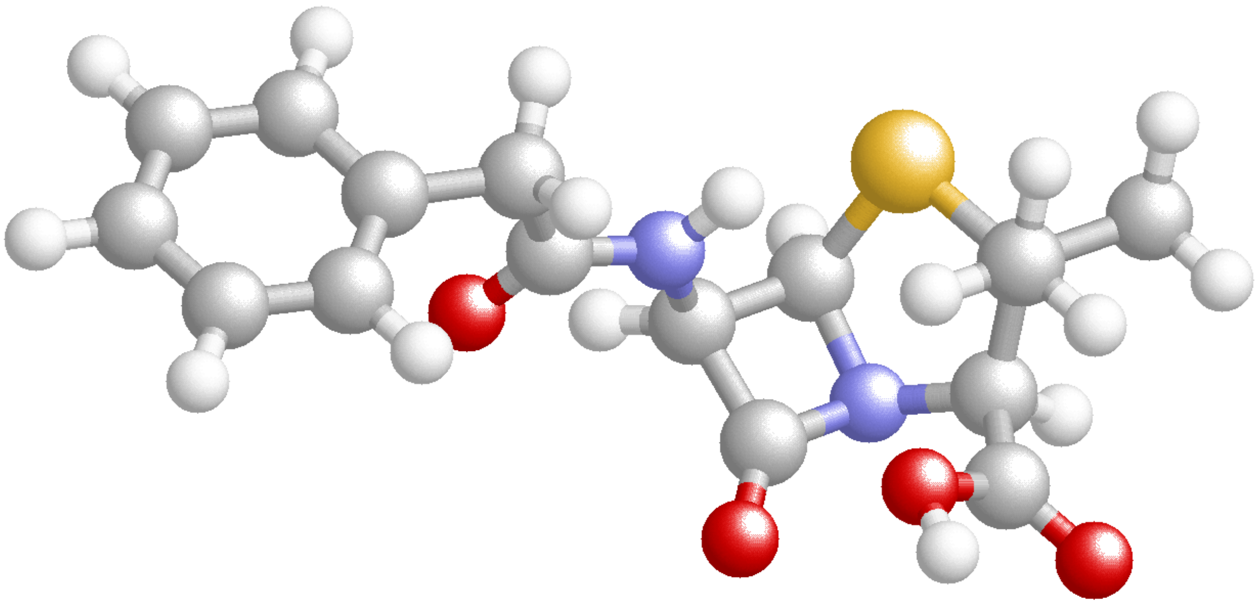
- *Atoms* are like tiny Lego bricks.
- Different bricks represent atoms of different *elements*.
- Just as different bricks can be put together to make different *models*, different atoms can be put together to make different *chemicals* or *compounds*.

Introduction to Atomic Structure – Models

Introduction to Atomic Structure – Models

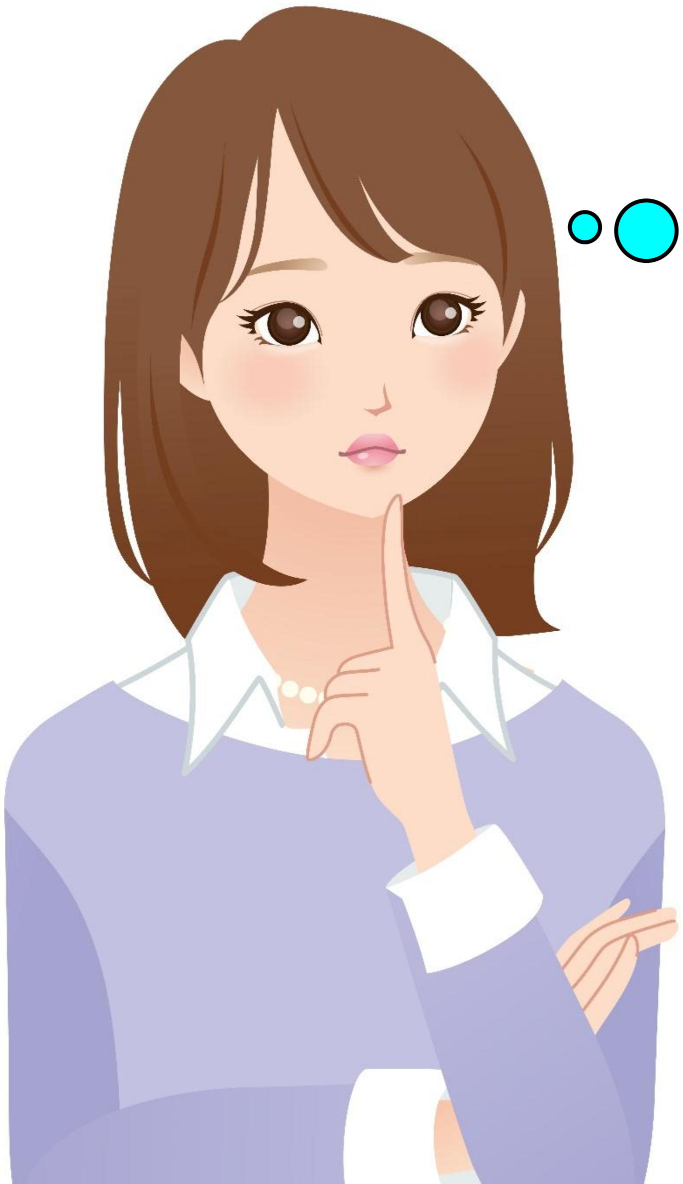
- “Lego bricks” for Chemists. Atoms of the different chemical elements.

Introduction to Atomic Structure – Models



- This is a computer generated *model* of a compound.
- The compound is made by putting different “building bricks” together.
- The “building bricks” used to make this compound are carbon atoms (grey), hydrogen atoms (white), nitrogen atoms (blue), oxygen atoms (red) and an atom of sulfur (yellow).

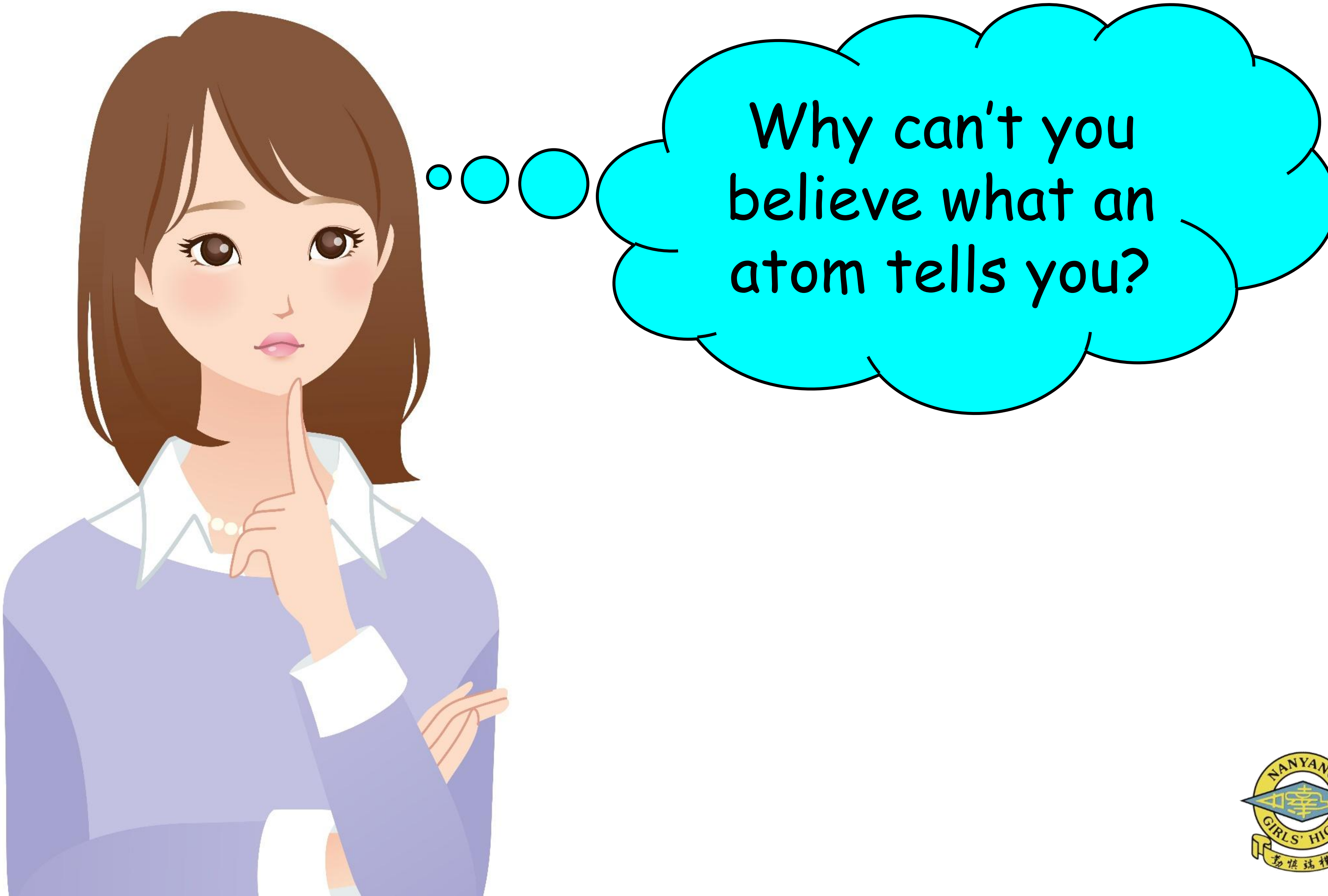
Introduction to Atomic Structure – Models



All *matter* is composed of *atoms*.

Note: Scientist also study *energy*. Scientists are interested to learn how *matter* and *energy* interact.

Introduction to Atomic Structure – Models



Introduction to Atomic Structure – Models

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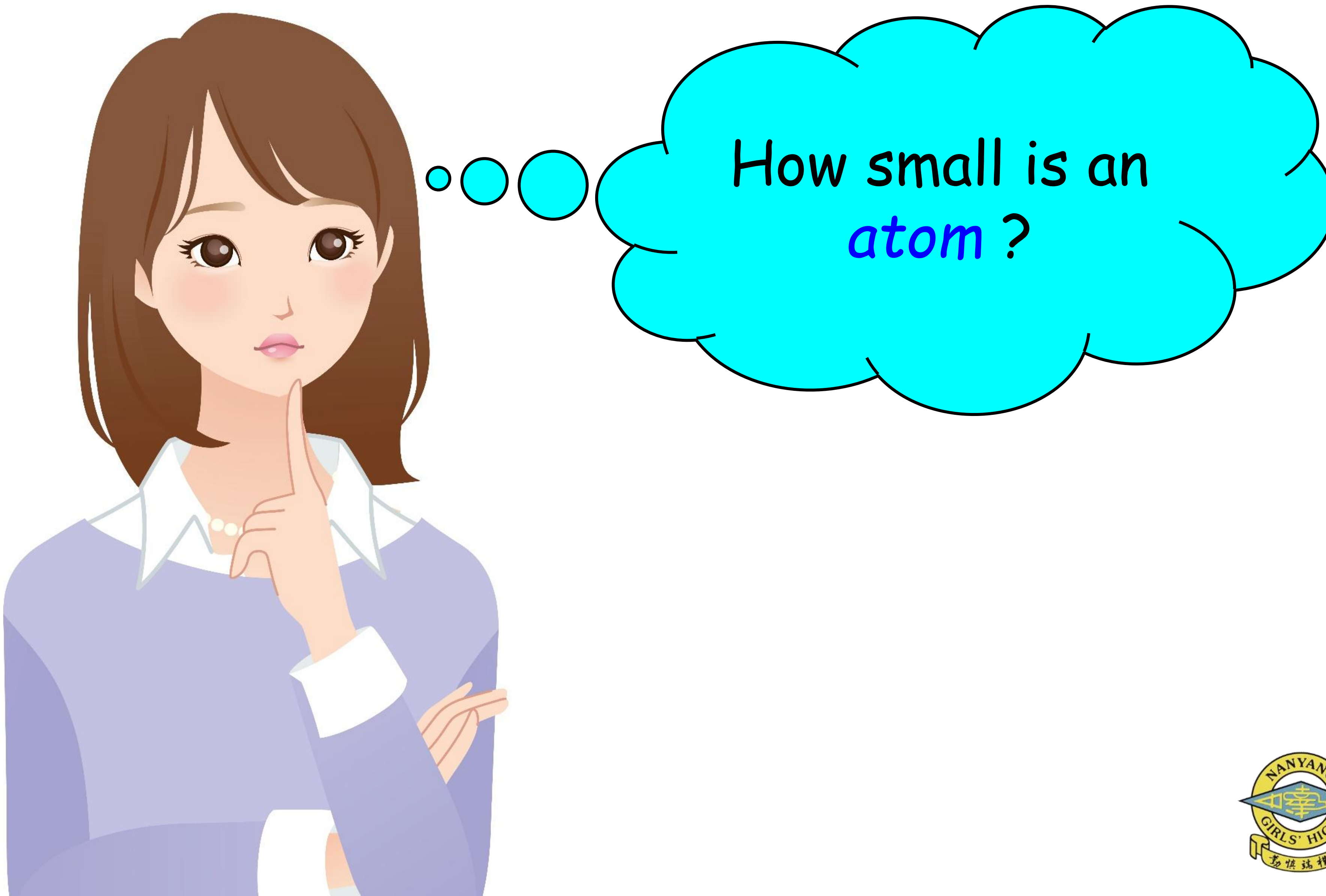

Introduction to Atomic Structure – Models

Introduction to Atomic Structure – Models

- There are approximately 5 – 10 times more stars in the known universe than there are grains of sand on all of the beaches around the world.
- But...
- There are more atoms in a single grain of sand than there are stars in the known universe.

Introduction to Atomic Structure – Models

- Two aluminium cans weigh approximately 27 grams. How many atoms of aluminium are there in the two cans?

Answer = 600 000 000 000 000 000 000 000 !

Introduction to Atomic Structure – Models

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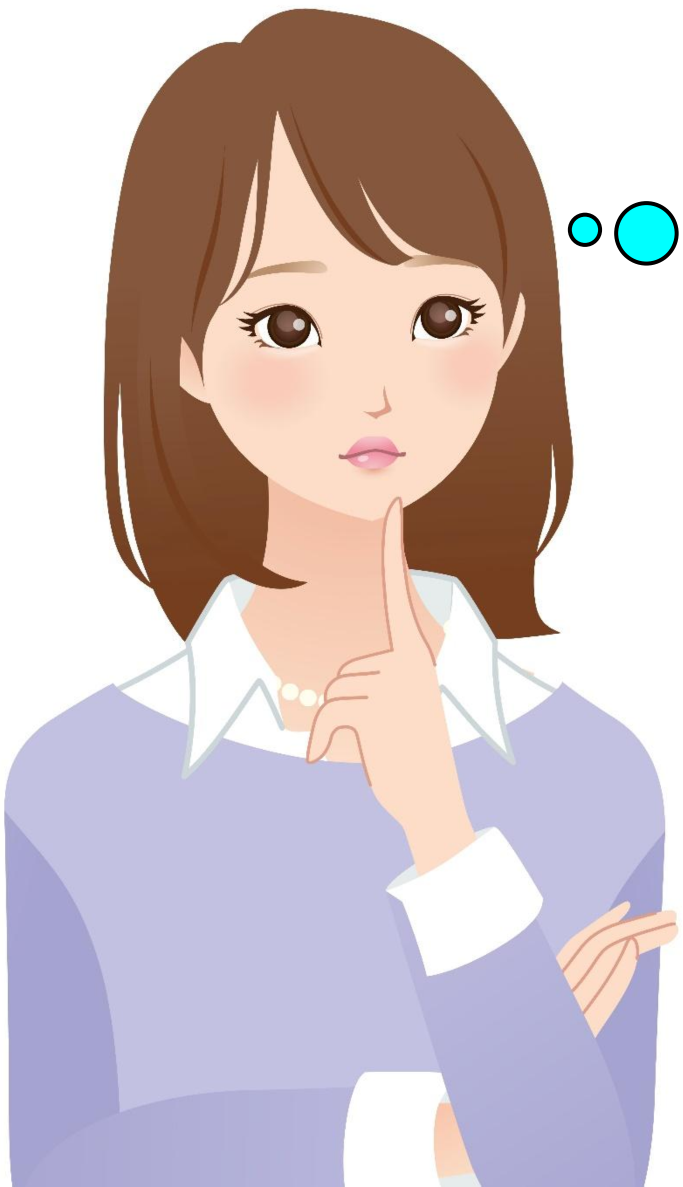
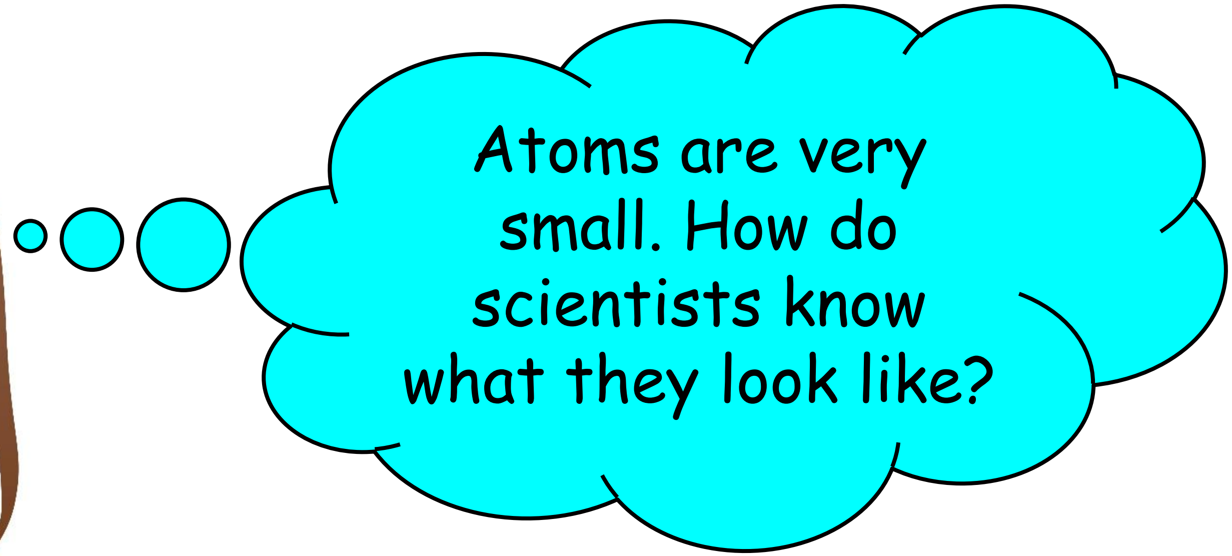
Answer = 600 000 000 000 000 000 000 000 !

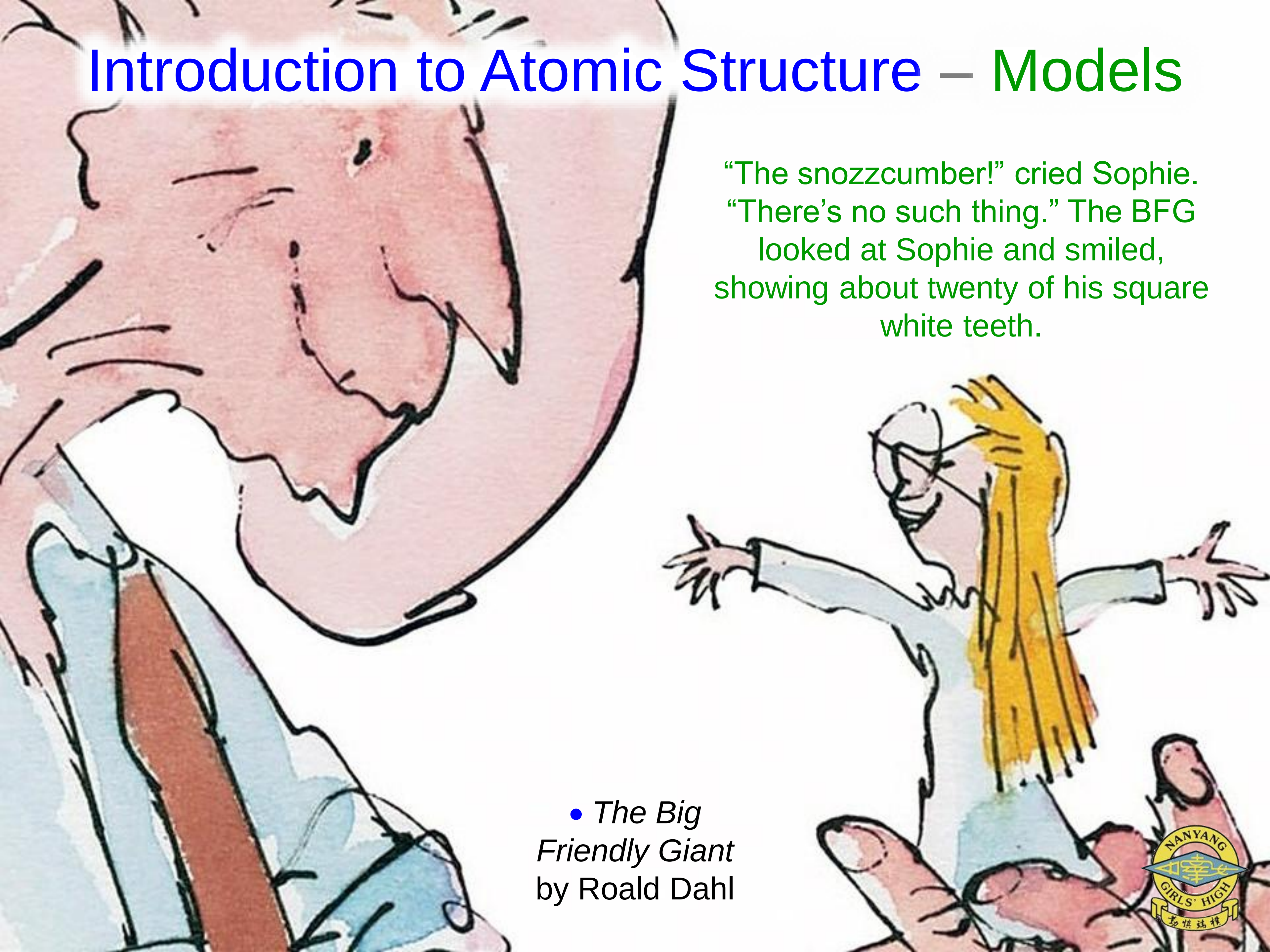
Introduction to Atomic Structure – Models





- Scientists use evidence from things that they *can* observe to infer information about things that they *cannot* observe directly.

Introduction to Atomic Structure – Models

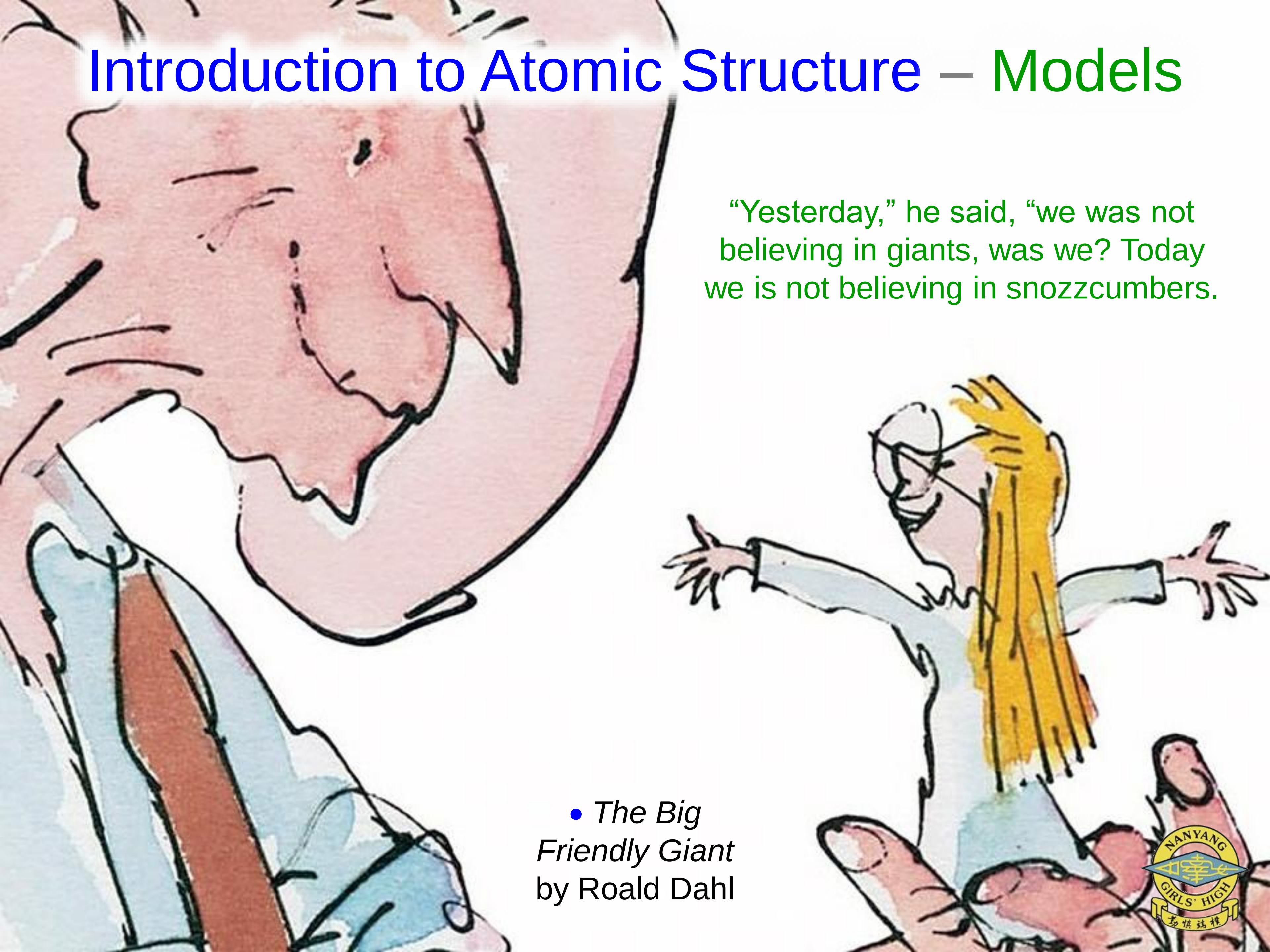


"The snozzcumber!" cried Sophie. "There's no such thing." The BFG looked at Sophie and smiled, showing about twenty of his square white teeth.

- *The Big Friendly Giant* by Roald Dahl

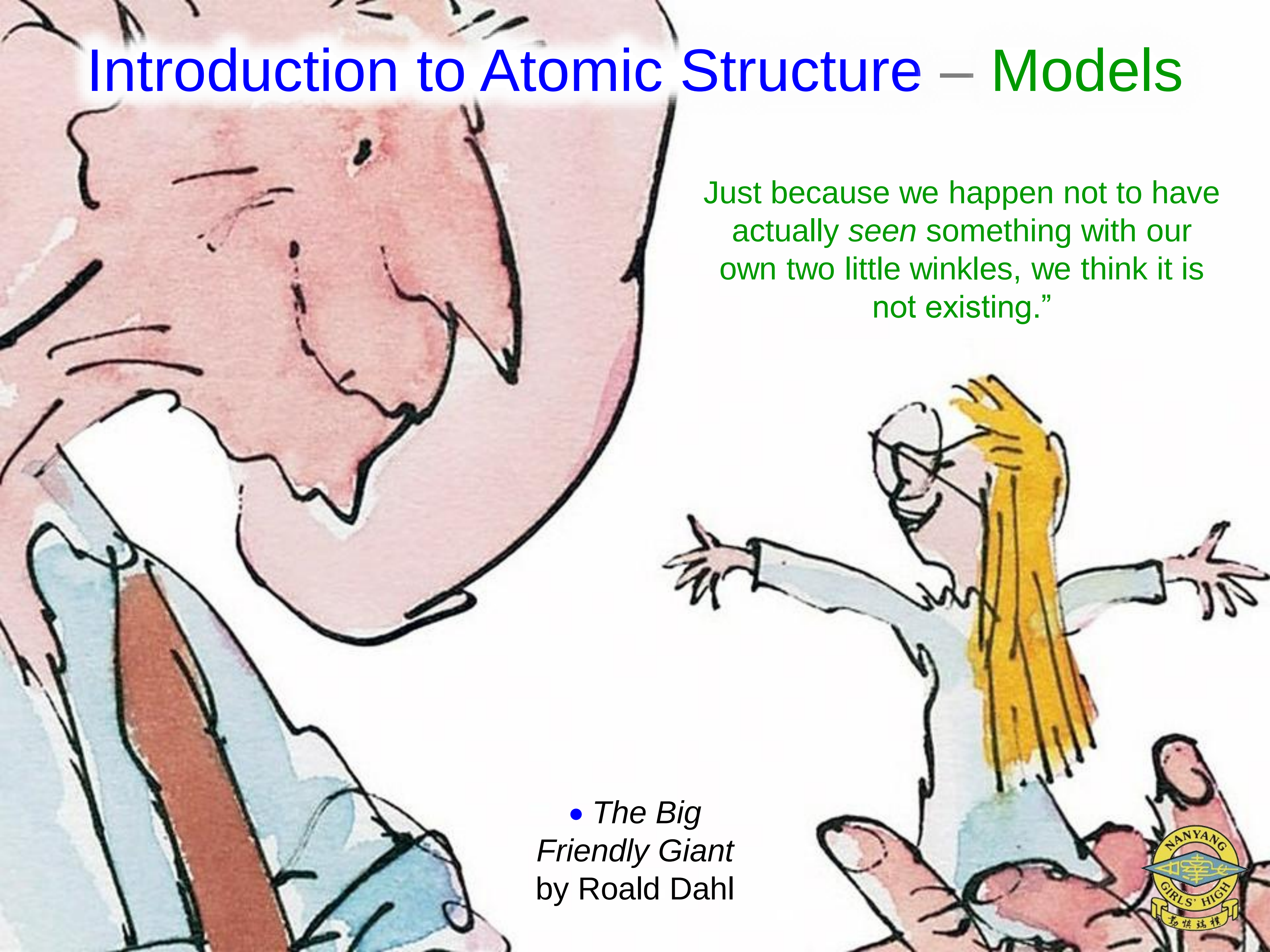
Introduction to Atomic Structure – Models

“Yesterday,” he said, “we was not believing in giants, was we? Today we is not believing in snozzcumbers.



- *The Big Friendly Giant* by Roald Dahl

Introduction to Atomic Structure – Models



Just because we happen not to have actually *seen* something with our own two little winkles, we think it is not existing."

- *The Big Friendly Giant* by Roald Dahl

Introduction to Atomic Structure – Models

What is the history of atomic structure?

Introduction to Atomic Structure – Models

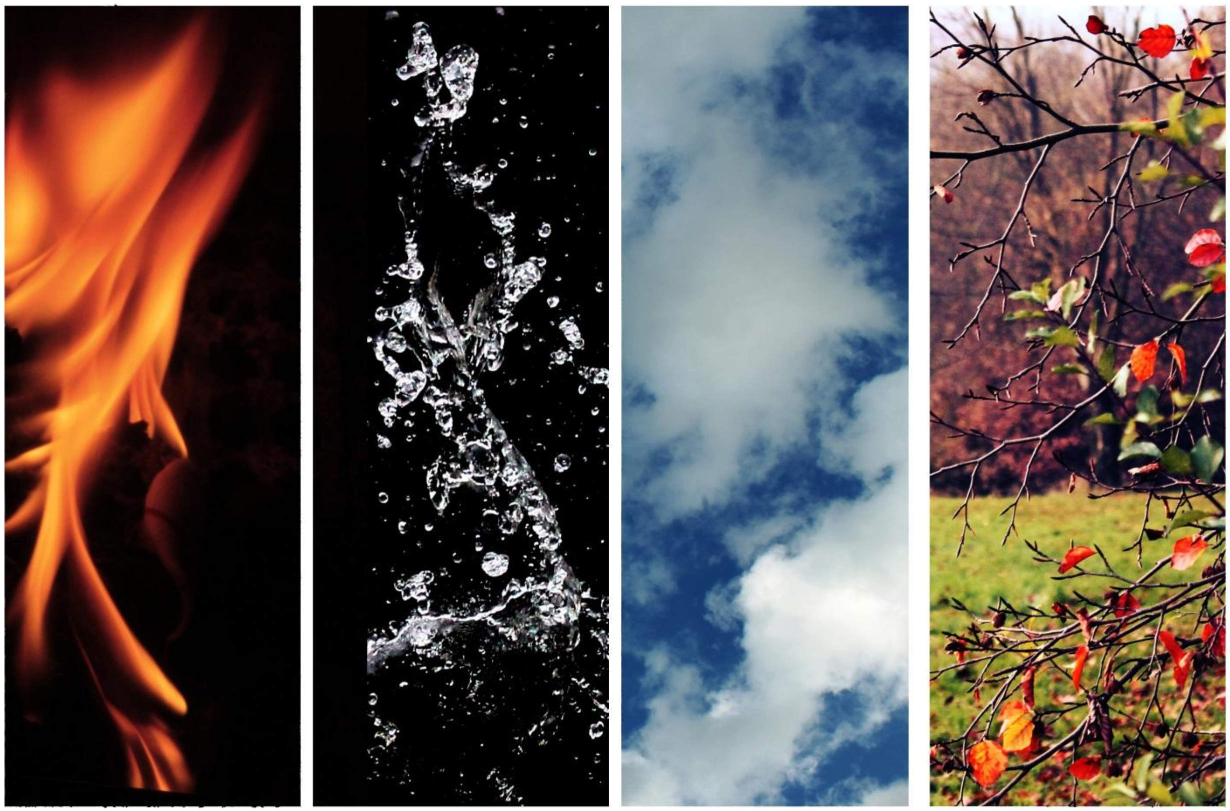
The Thinker
Auguste Rodin (1880)

Fundamental Questions in Chemistry…

- What is matter composed of?
- What holds matter together?
- How are matter and energy related?

Introduction to Atomic Structure – Models

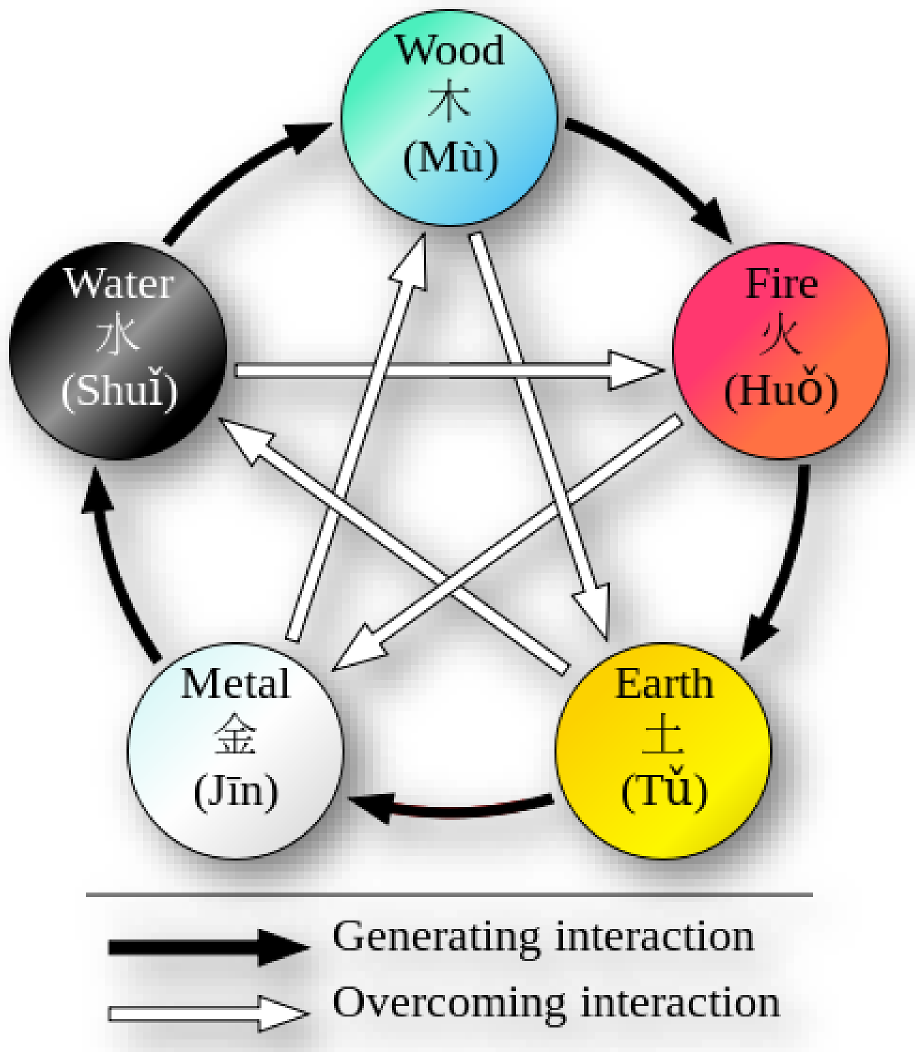
Ancient ideas about what matter is composed of…



- Fire
- Water
- Air
- Earth

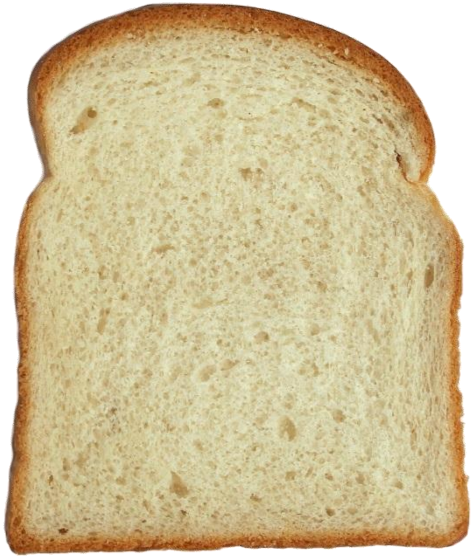
Introduction to Atomic Structure – Models

Ancient ideas about what matter is composed of…



Introduction to Atomic Structure – Models

- Is matter infinitely divisible?



Introduction to Atomic Structure – Models

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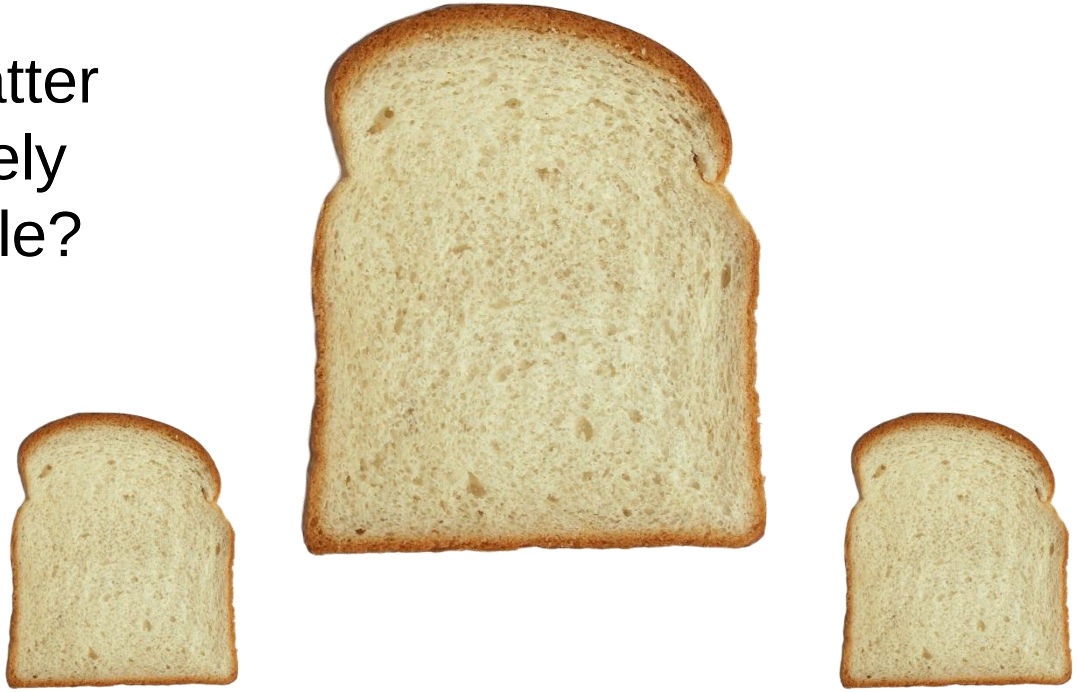
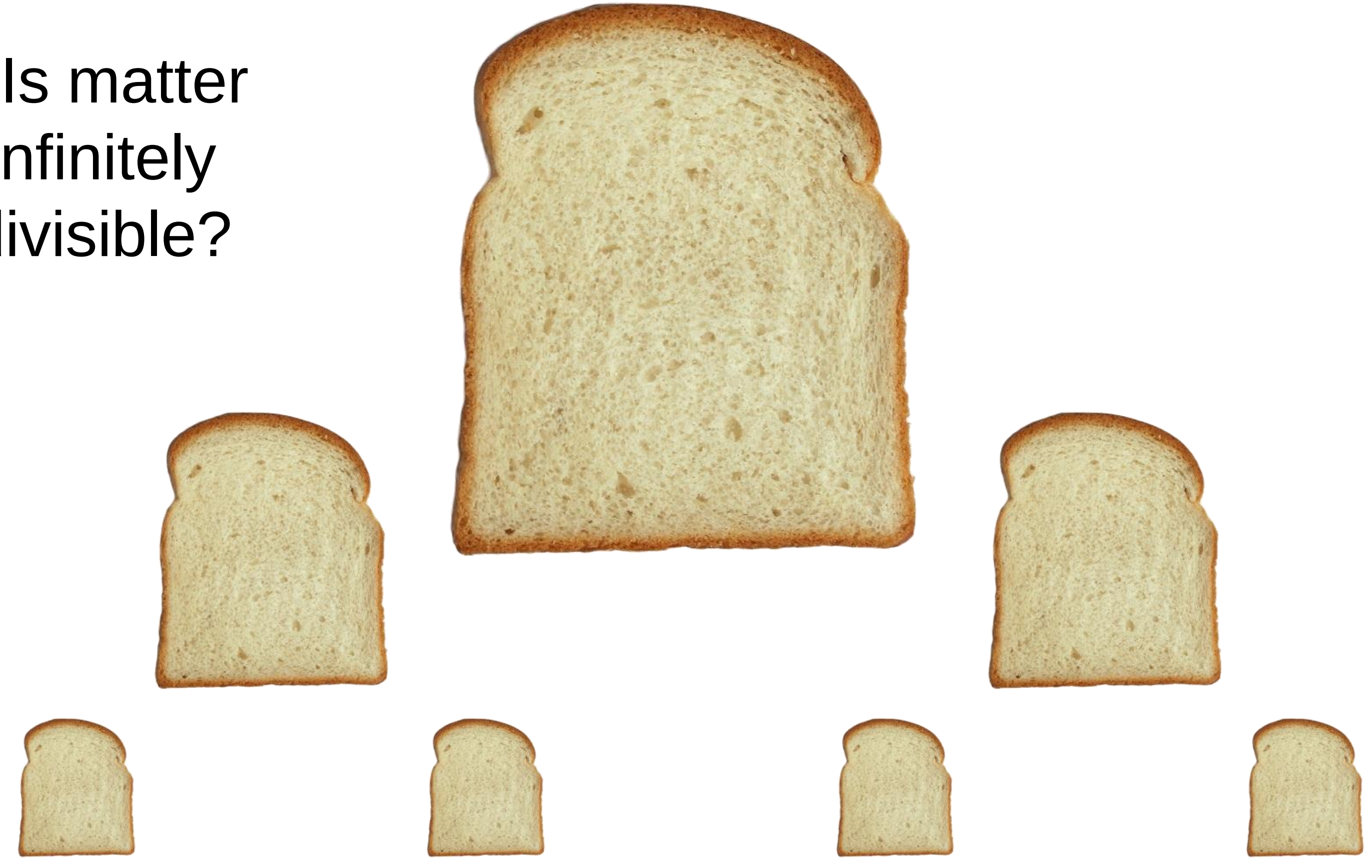


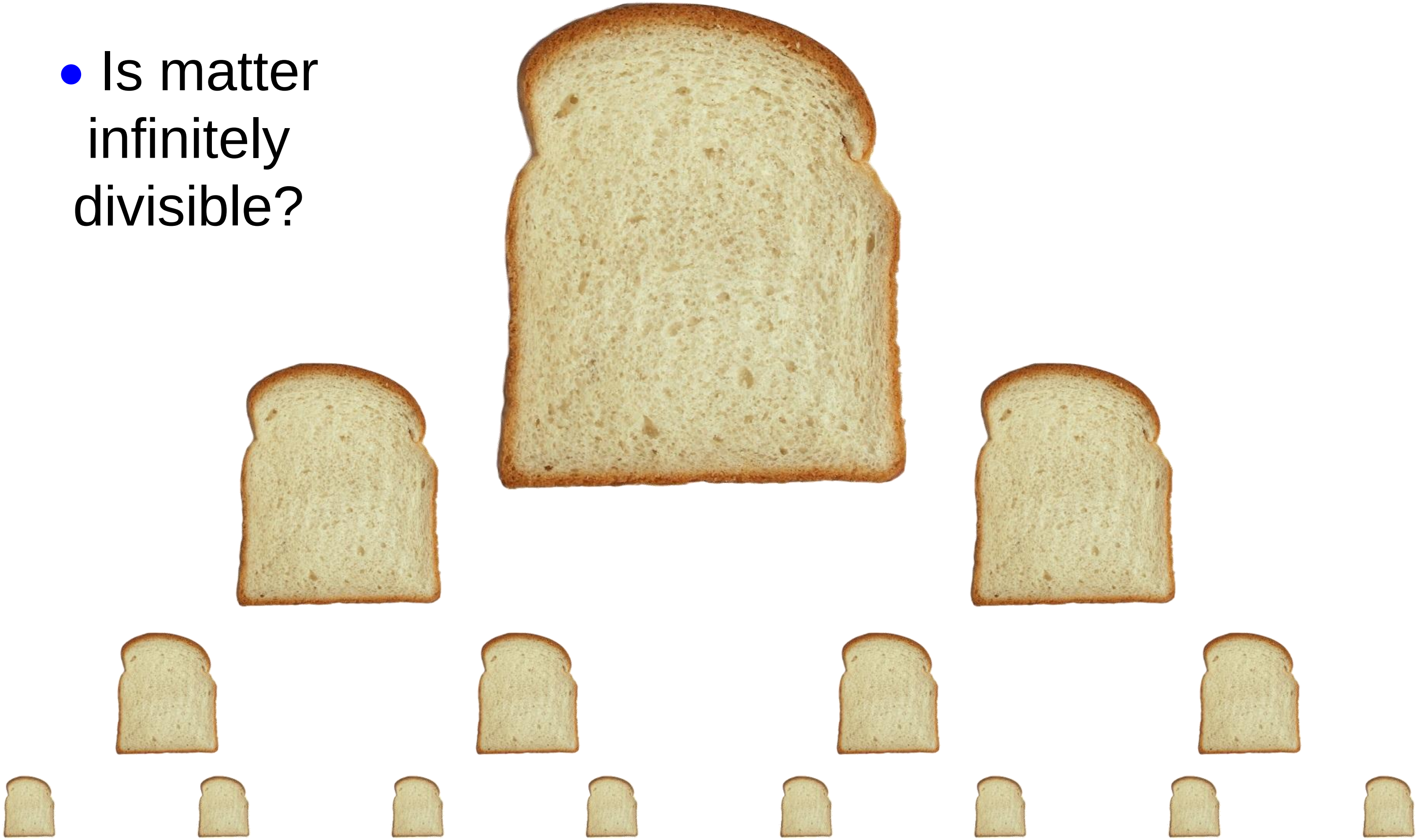
Introduction to Atomic Structure – Models

- Is matter infinitely divisible?



Introduction to Atomic Structure – Models

- Is matter infinitely divisible?



Introduction to Atomic Structure – Models

Introduction to Atomic Structure – Models

- The Greek Philosopher Democritus, who lived 2500 years ago, was the first to suggest the idea of *atoms*.

- While walking on a beach Democritus saw rocks being broken into pebbles and pebbles being broken into sand. He reasoned that eventually there must be tiny pieces of rock that cannot be broken down into anything smaller.

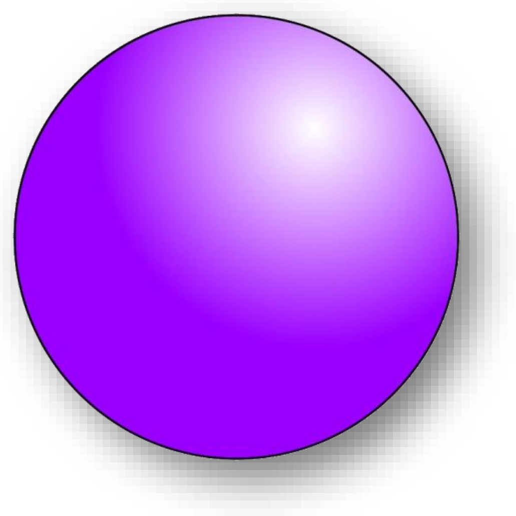
Introduction to Atomic Structure – Models

- Democritus's story is a good example of how scientific concepts can be inspired by everyday observations. He noticed the natural process of rocks weathering and breaking down into pebbles and then sand. This led him to the important idea that matter is not infinitely divisible, but is composed of fundamental, indivisible units. These units, which he called *atomos*, are the building blocks of everything in the universe.

Introduction to Atomic Structure – Models

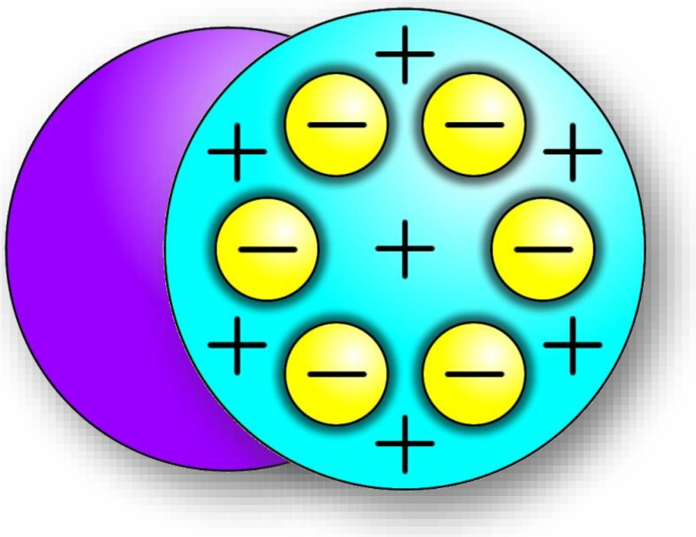
- The word *atom* is derived from the Greek word *atomos*.
  - The negative prefix *a* means *not*. The root *tomos* means *cut*.
- So the literal translation of *atomos* is *cannot be cut*.

Introduction to Atomic Structure – Models



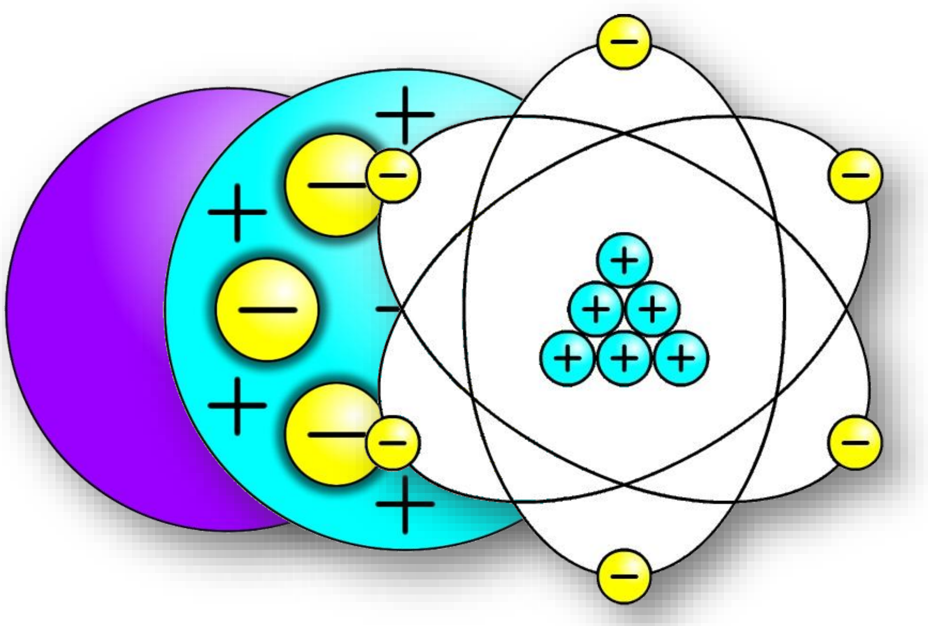
- Dalton's Atom

Introduction to Atomic Structure – Models



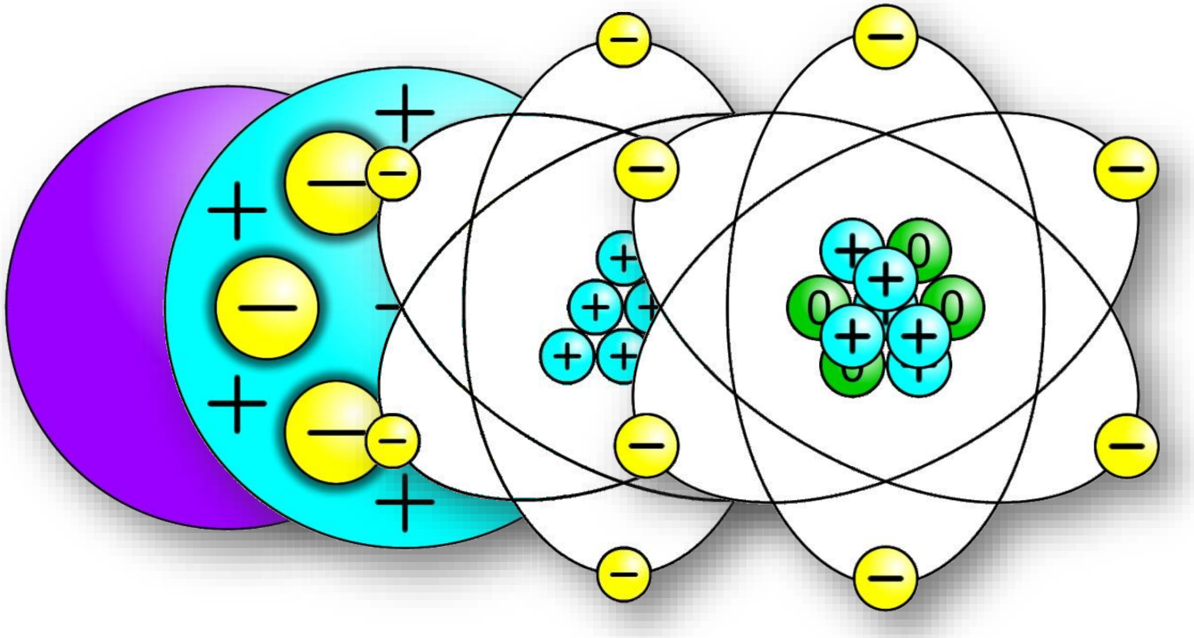
- Dalton's Atom
- Thomson's Atom

Introduction to Atomic Structure – Models



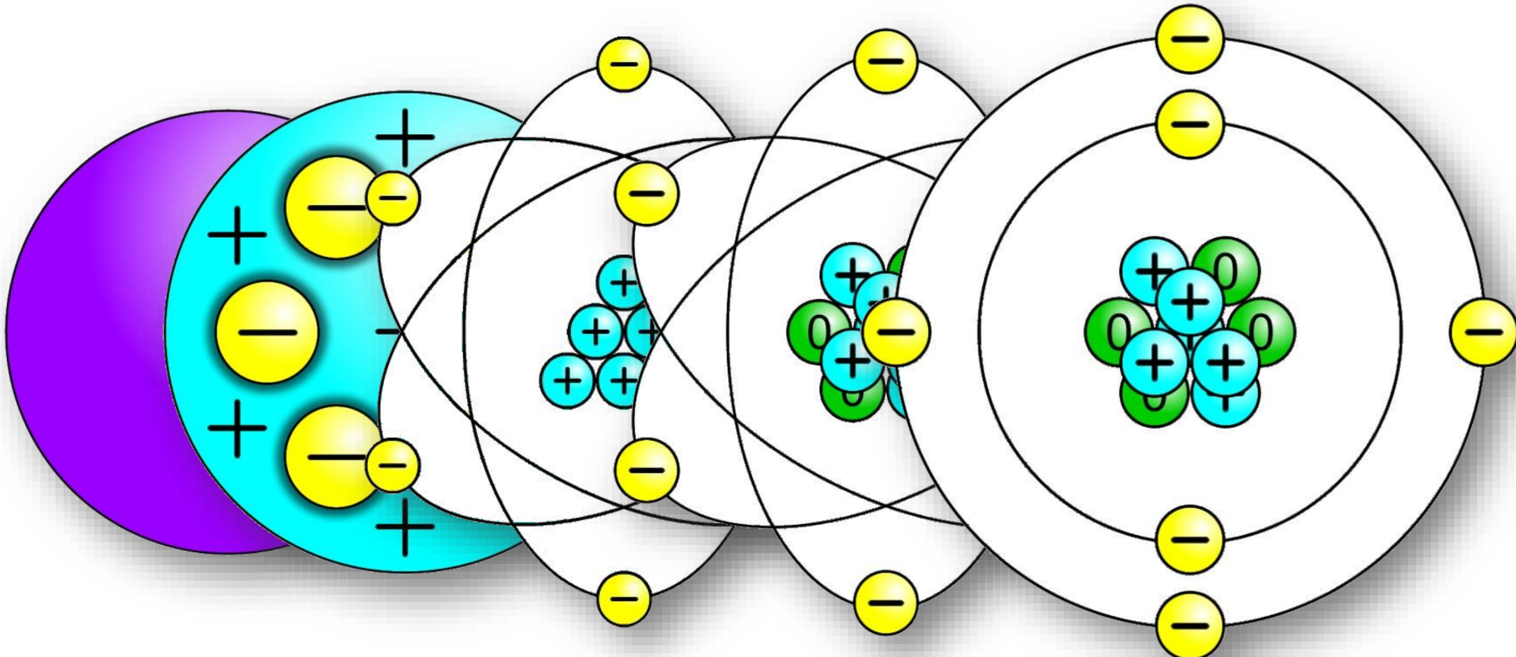
- Dalton's Atom
- Thomson's Atom
- Rutherford's Atom

Introduction to Atomic Structure – Models



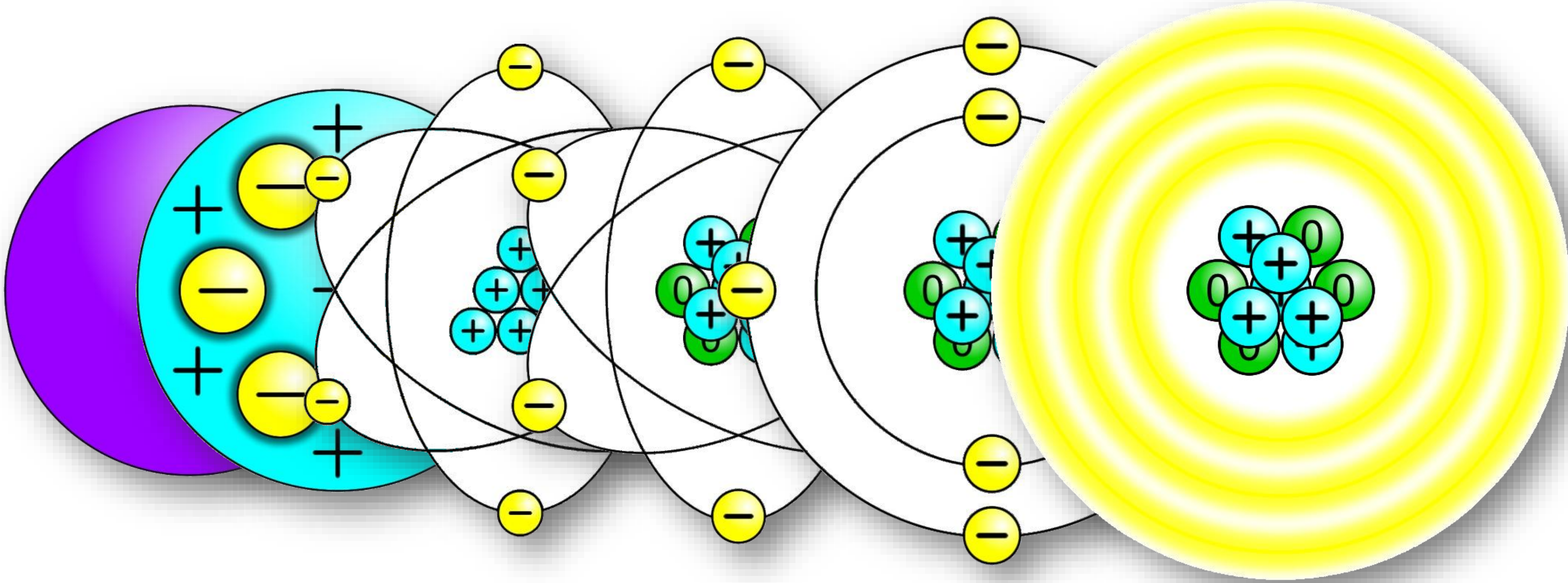
- Dalton’s Atom
- Thomson’s Atom
- Rutherford’s Atom
- Chadwick’s Atom

Introduction to Atomic Structure – Models



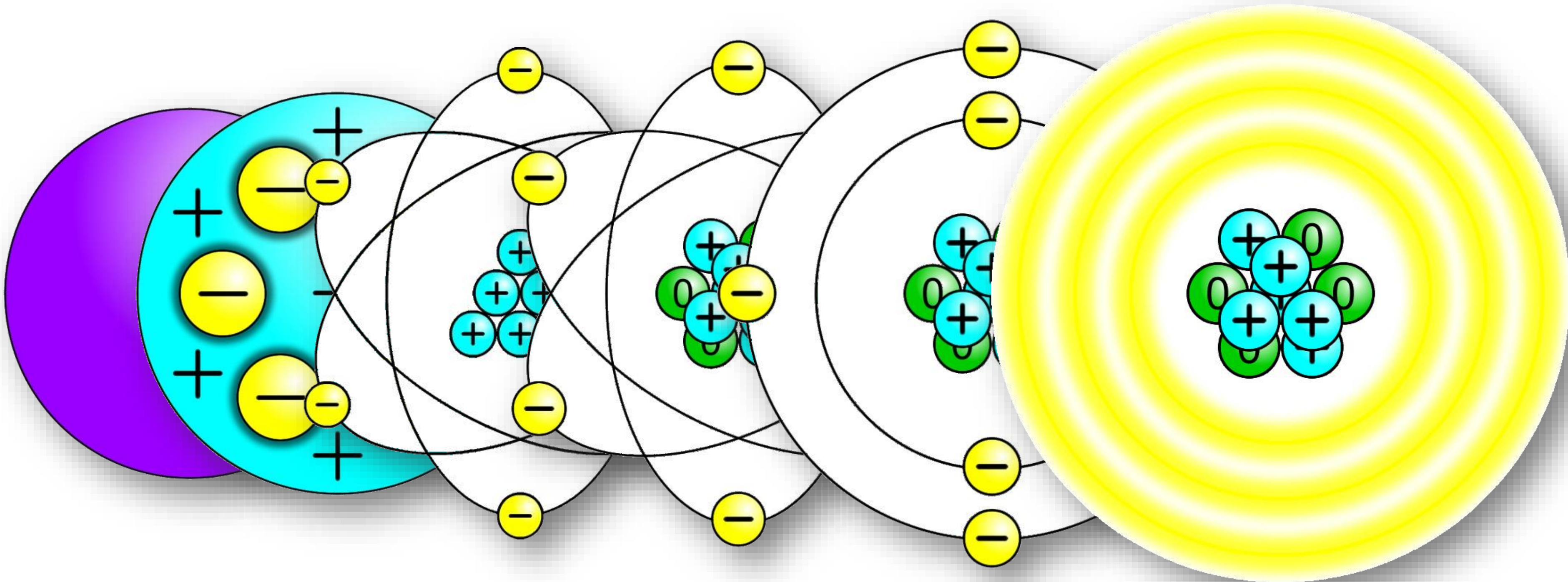
- Dalton's Atom
- Thomson's Atom
- Rutherford's Atom
- Chadwick's Atom
- Bohr's Atom

Introduction to Atomic Structure – Models



- Dalton's Atom
- Thomson's Atom
- Rutherford's Atom
- Chadwick's Atom
- Bohr's Atom
- Schrödinger's Atom

Introduction to Atomic Structure – Models



Enduring Understandings

- Science is a *human endeavour*.
- Scientific discoveries are made through *collaboration* and by building upon the work of others over a period of time.

Introduction to Atomic Structure – Models

John Dalton
1766 – 1844

John Dalton

- All matter is composed of indivisible particles called atoms.
- Atoms of the same element have the same physical and chemical properties.
- Atoms of different elements have different physical and chemical properties.

Introduction to Atomic Structure – Models

John Dalton
1766 – 1844

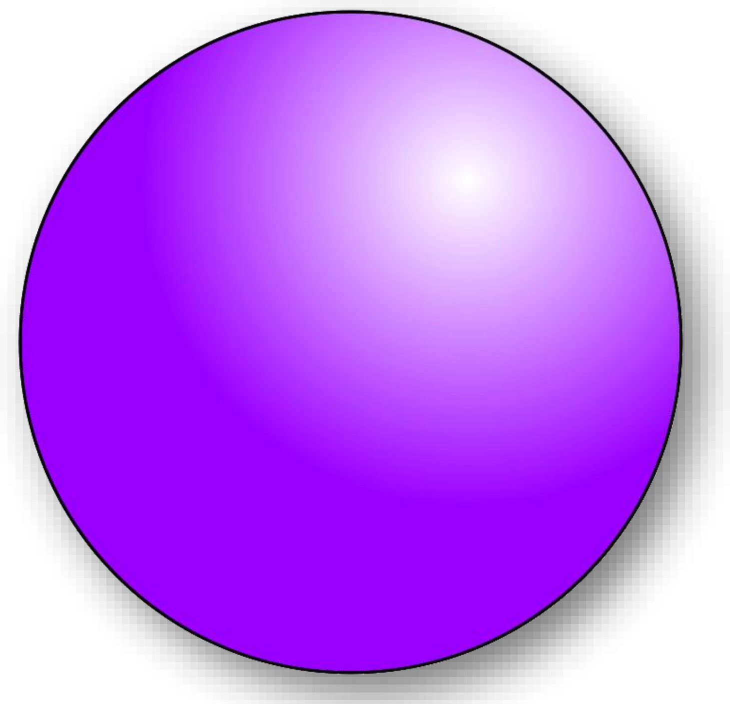
John Dalton

- Two or more atoms of different elements can chemically combine in simple whole number ratios to form compounds.
- Atoms cannot be subdivided, created or destroyed when involved in a chemical reaction.
- Dalton’s theory is based on observations of chemical reactions.

Introduction to Atomic Structure – Models

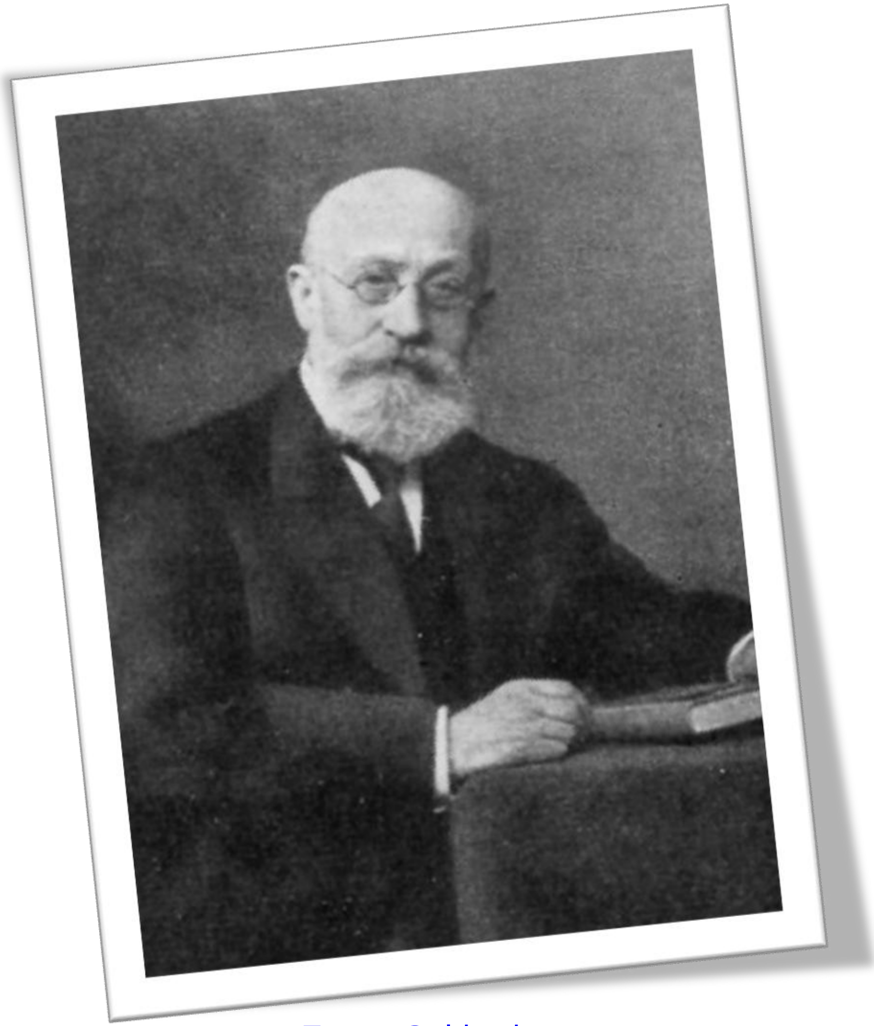
John Dalton
1766 – 1844

John Dalton



- Dalton's atom.

Introduction to Atomic Structure – Models

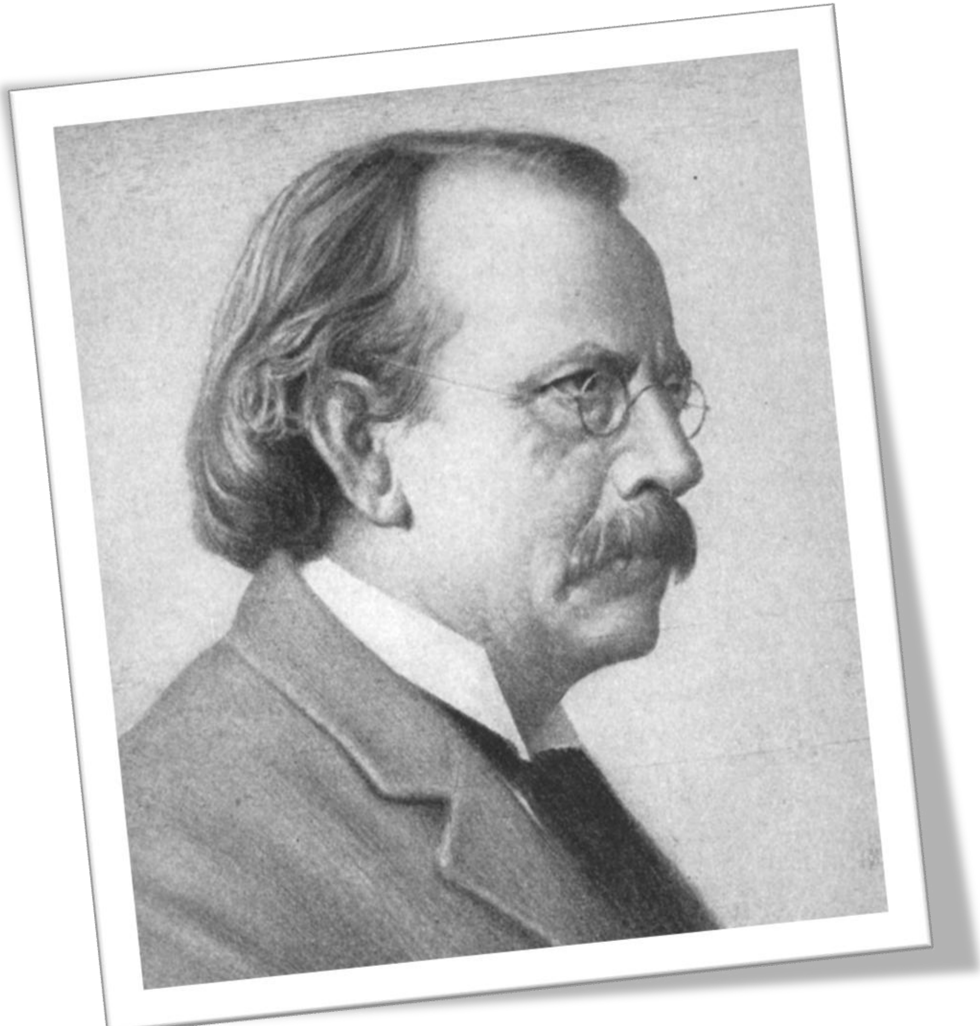


Eugne Goldstein
1850 – 1930

Eugne Goldstein

- Discovered that discharge tubes can produce a glow at both the anode (positive) end and the cathode (negative) end.
- He concluded that in addition to the already-known cathode rays (recognised as electrons moving from the negatively charged cathode towards the positive charged anode) there is another ray that travels in the opposite direction.
- The anode ray with the smallest mass comes from hydrogen gas, and is made of hydrogen ions, which are *protons*.

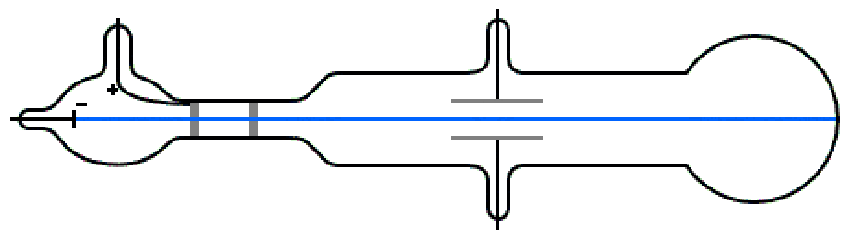
Introduction to Atomic Structure – Models



J. J. Thomson
1856 – 1940
Awarded the Nobel Prize
for Physics in 1906.

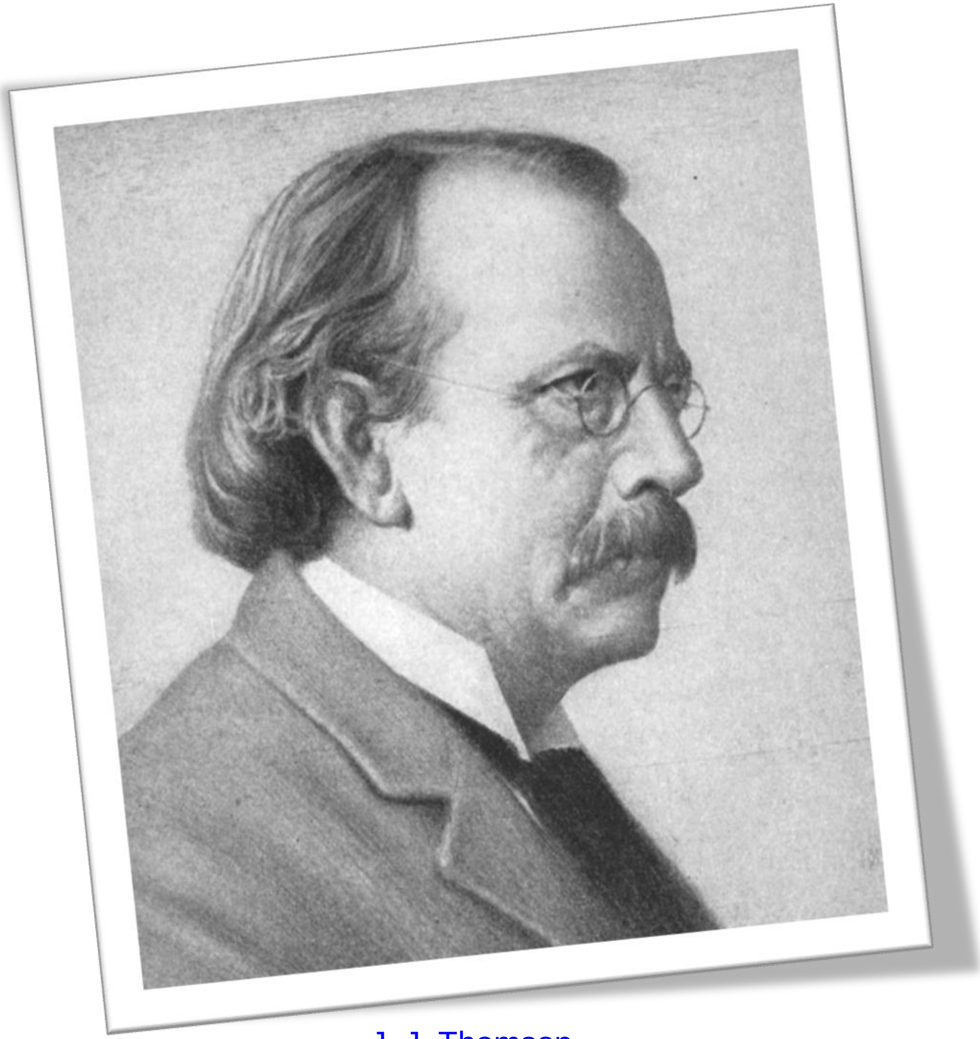
Joseph John Thomson

- Discovered the *electron* while performing experiments on cathode rays.



- The discovery of the *electron* proved that the atom is *not indivisible*.
- Proposed the "*plum pudding*" model of the atom.

Introduction to Atomic Structure – Models



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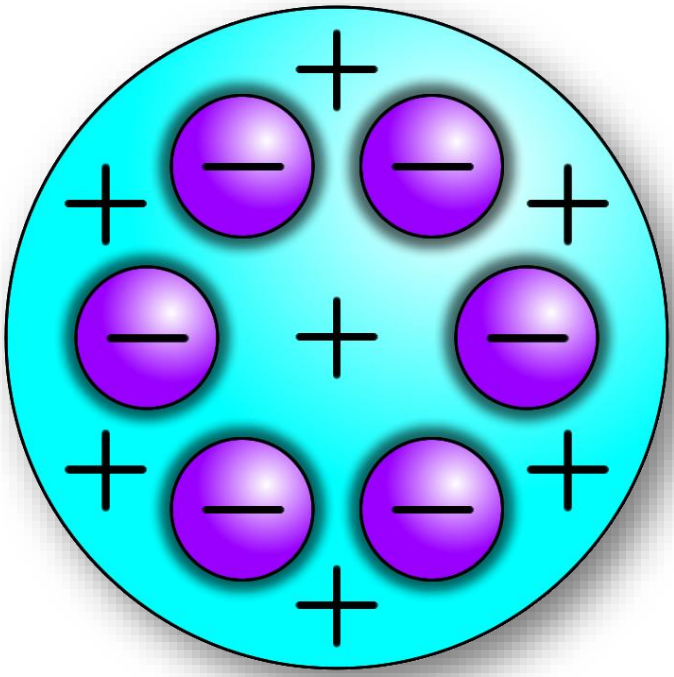
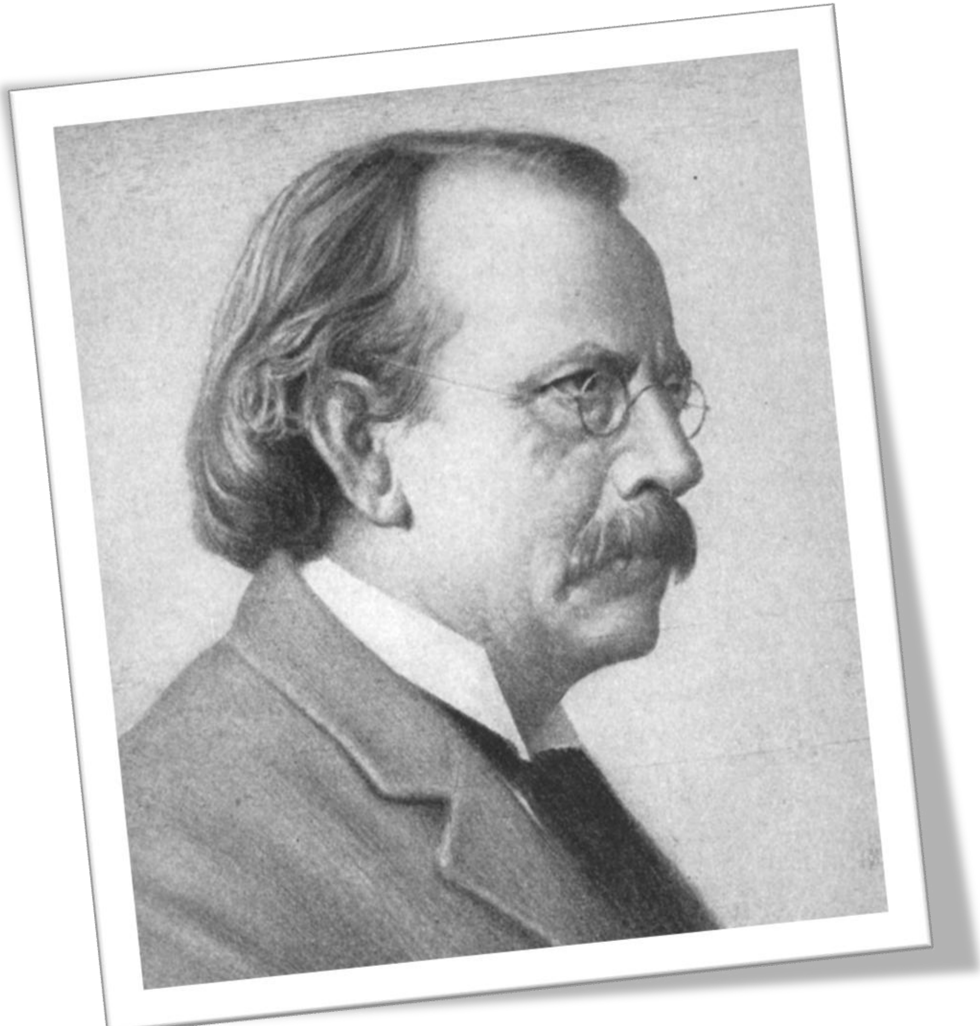


- Thomson's atom.

Introduction to Atomic Structure – Models



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1856 – 1940
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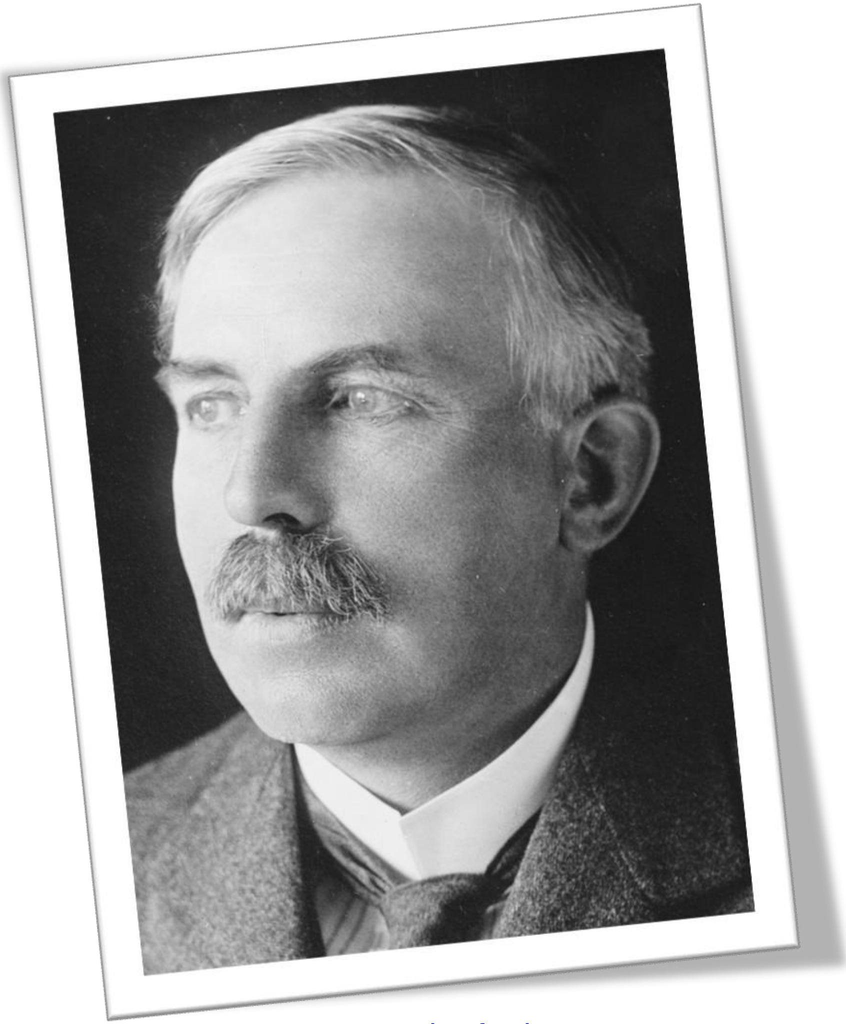
Joseph John Thomson

- Thomson's model of the atom is often referred to as the "*plum pudding*" model.

Introduction to Atomic Structure – Models

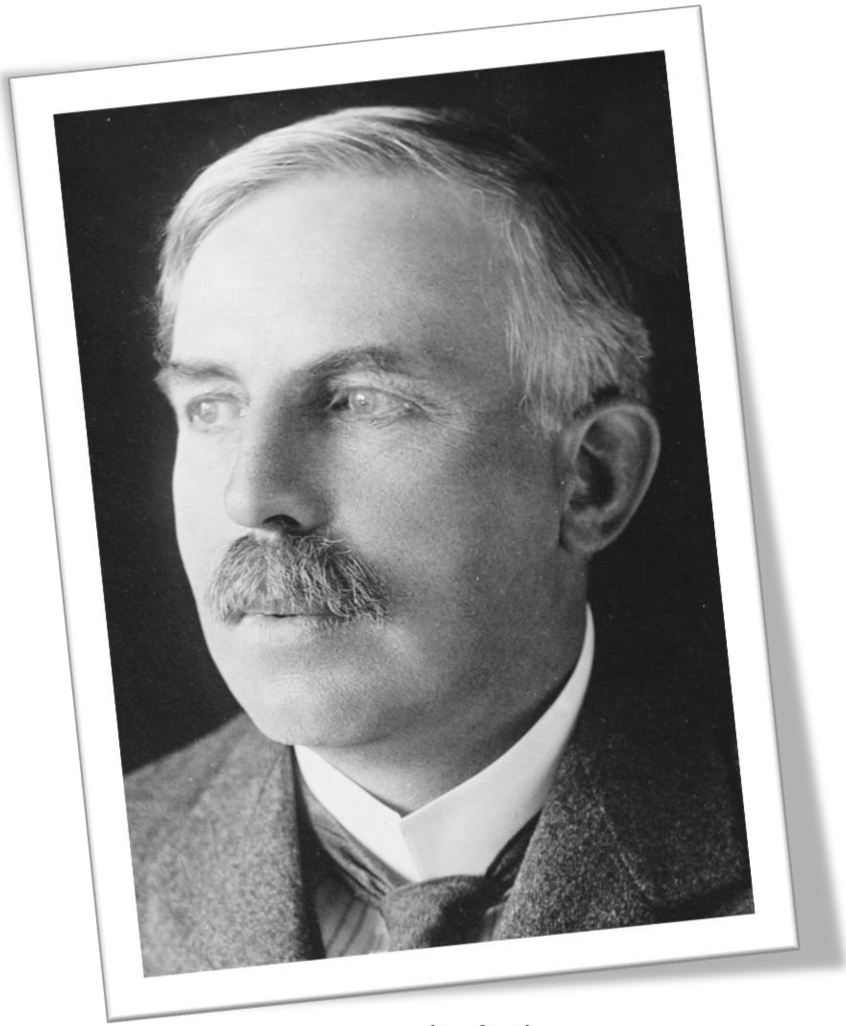


Ernest Rutherford
1871 – 1937
(Student of J. J. Thomson)
Awarded the Nobel Prize for Chemistry in 1908.

Ernest Rutherford

- Fired alpha particles at a piece of gold foil.
- Most of the alpha particles went straight through the gold foil, demonstrating that atoms are mostly empty space.
- However, some of the alpha particles were deflected through very large angles, demonstrating that there is a small, dense, positive nucleus at the centre of each atom.

Introduction to Atomic Structure – Models



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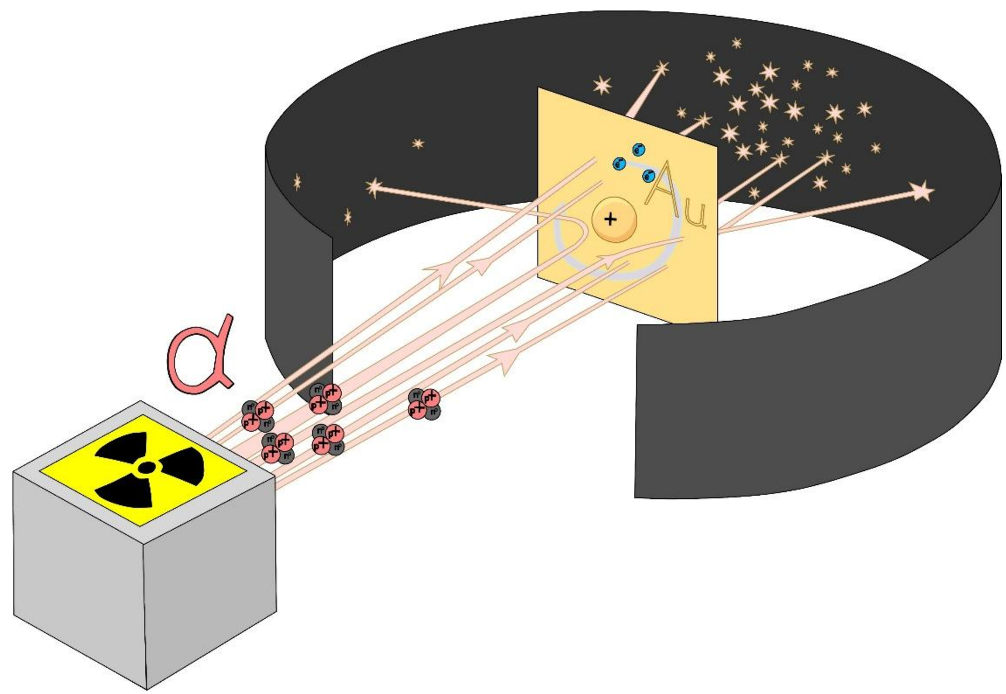
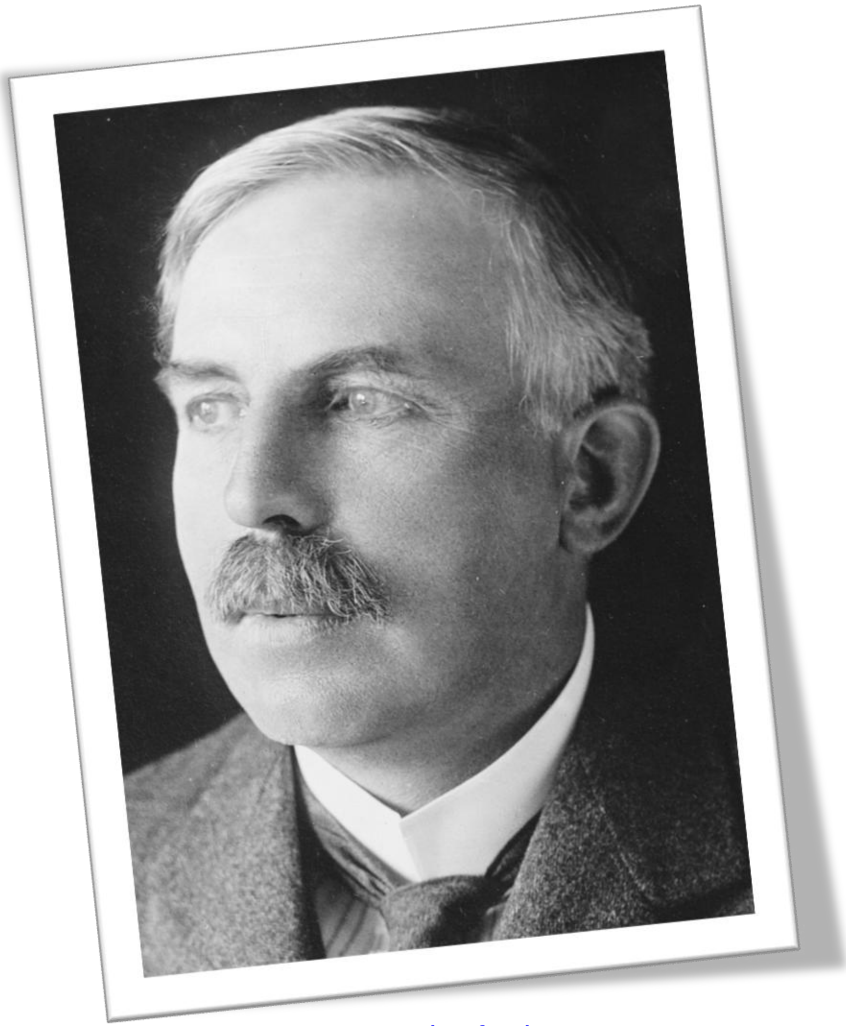


Introduction to Atomic Structure – Models



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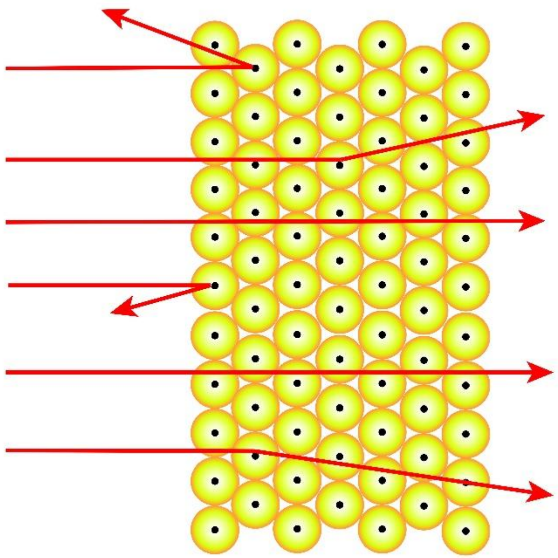
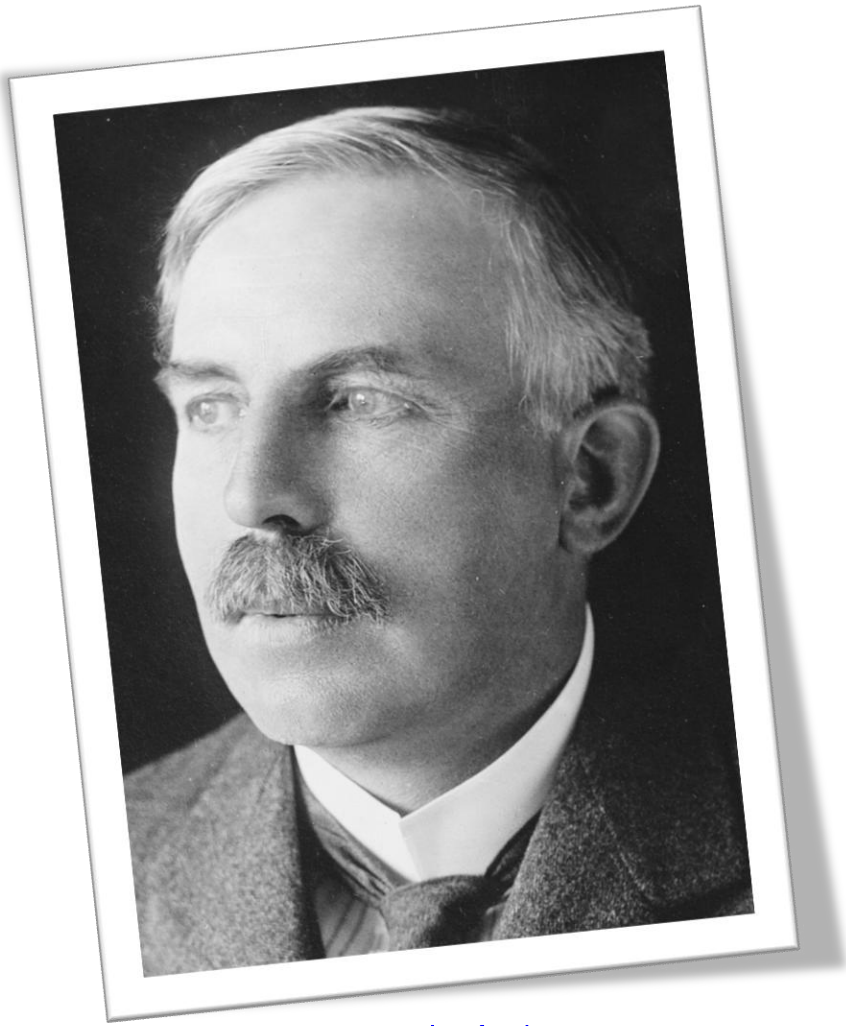


- The results of Rutherford's experiment demonstrate that atoms are mostly empty space, but each atom has a small, dense nucleus at its centre.

Introduction to Atomic Structure – Models



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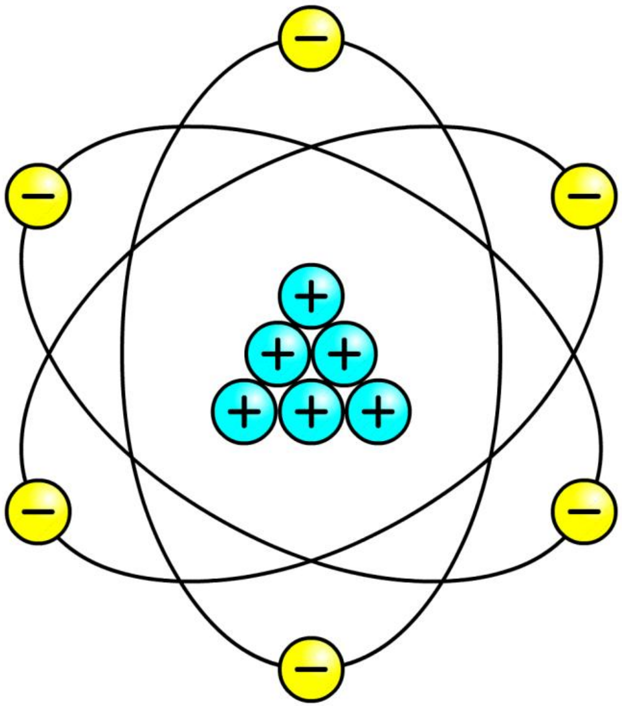


- Rutherford's atom.

Introduction to Atomic Structure – Models

James Chadwick
1891 – 1974
(Student of Rutherford)
Awarded the Nobel Prize for Physics in 1935.

James Chadwick

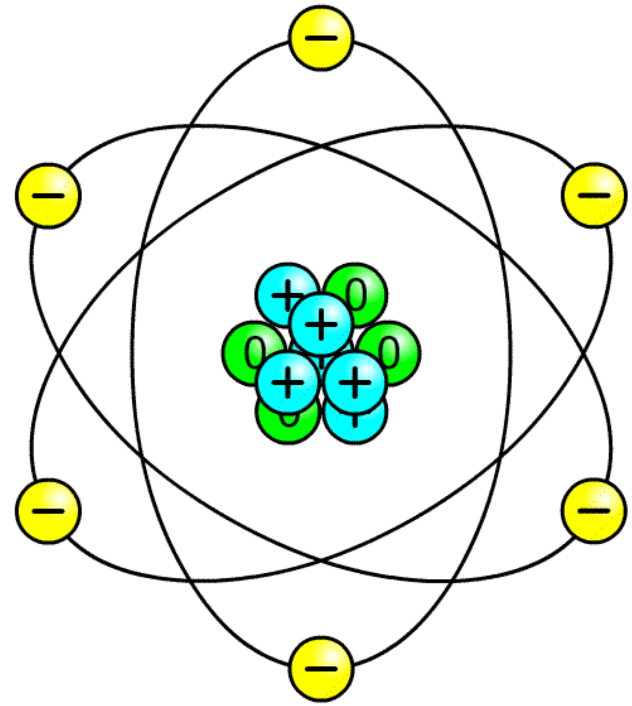
- Bombarded atoms of beryllium with alpha particles.

- Discovered that neutral particles are emitted when the beryllium nucleus and alpha particles fuse together. The neutral particles are *neutrons*.

Introduction to Atomic Structure – Models

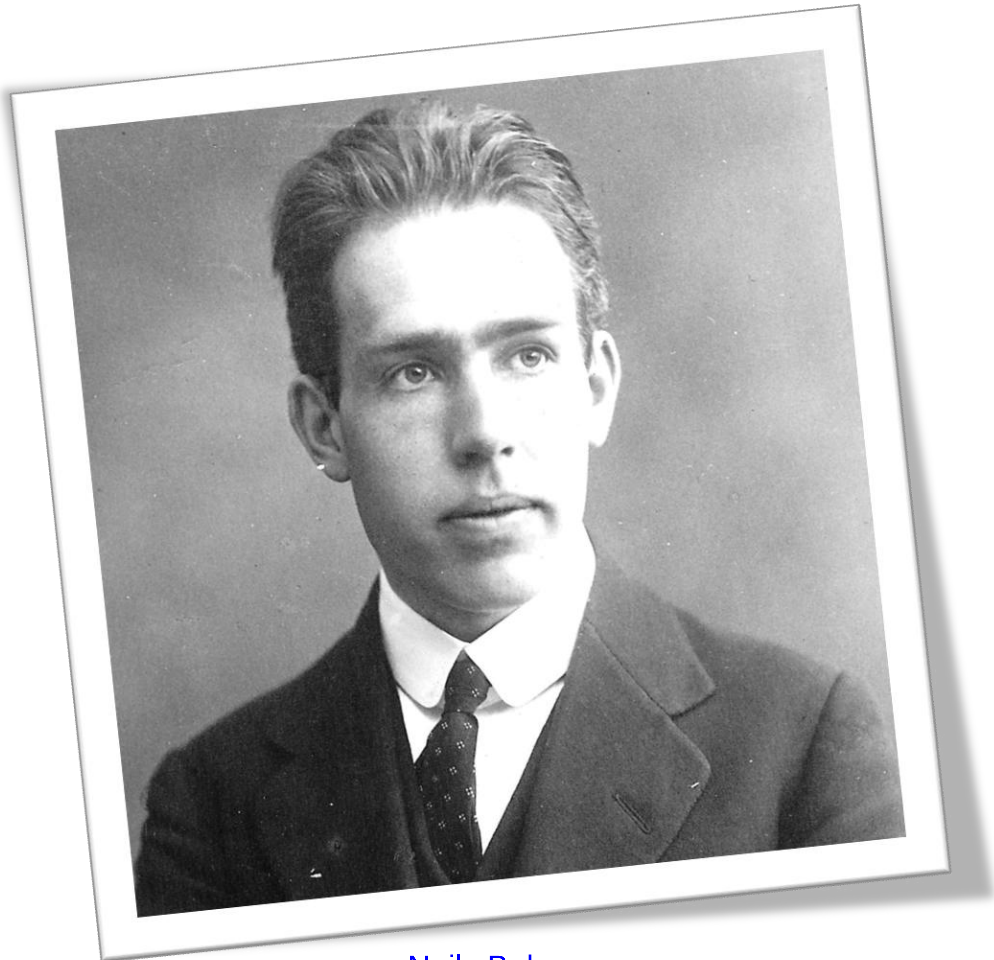
James Chadwick
1891 – 1974
(Student of Rutherford)
Awarded the Nobel Prize for
Physics in 1935.

James Chadwick



- Chadwick's atom.

Introduction to Atomic Structure – Models



Neils Bohr
1891 – 1973
(Student of Rutherford)
Awarded the Nobel Prize for Physics in 1922.

Niels Bohr

- Rutherford's *model* of the atom was modified by Niels Bohr.
- Bohr said that electrons are only allowed to move in certain orbits.
- When electrons absorb energy, they will move from lower energy orbit to higher energy orbit.
- When electrons move from higher energy orbit to lower energy orbit, they will emit energy.

Introduction to Atomic Structure – Models

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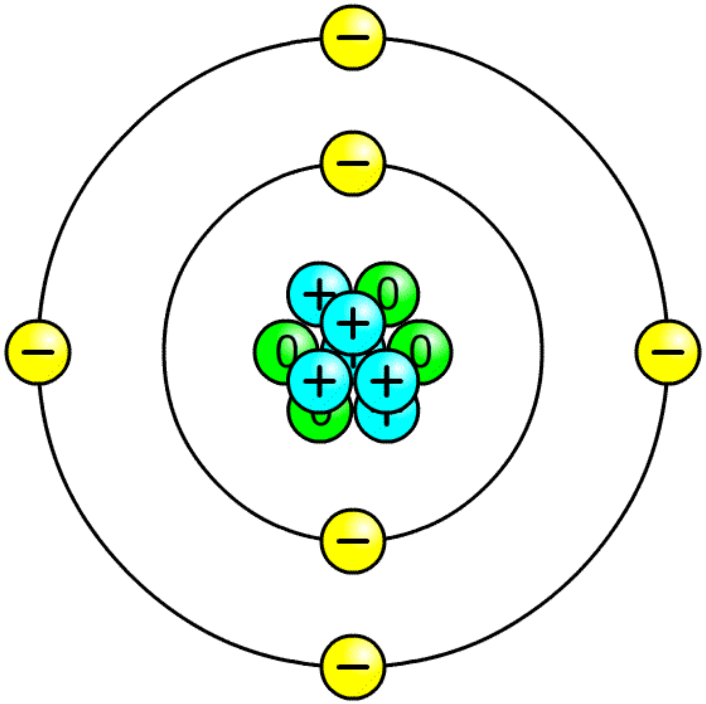
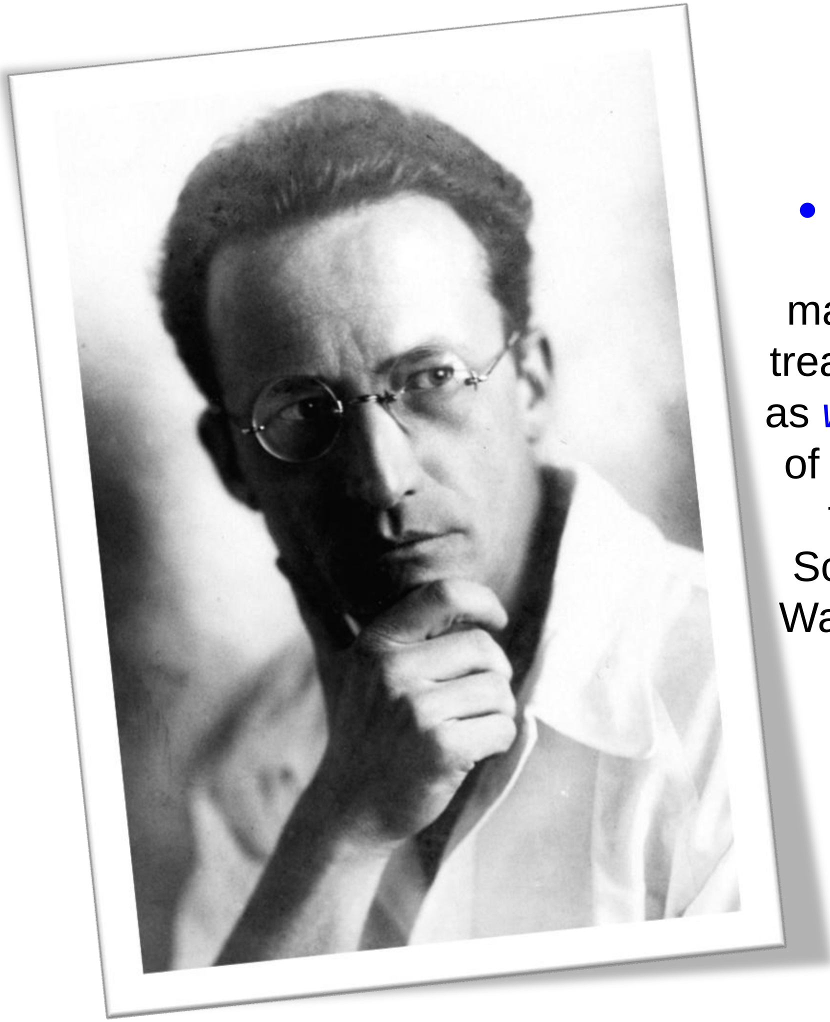
Niels Bohr



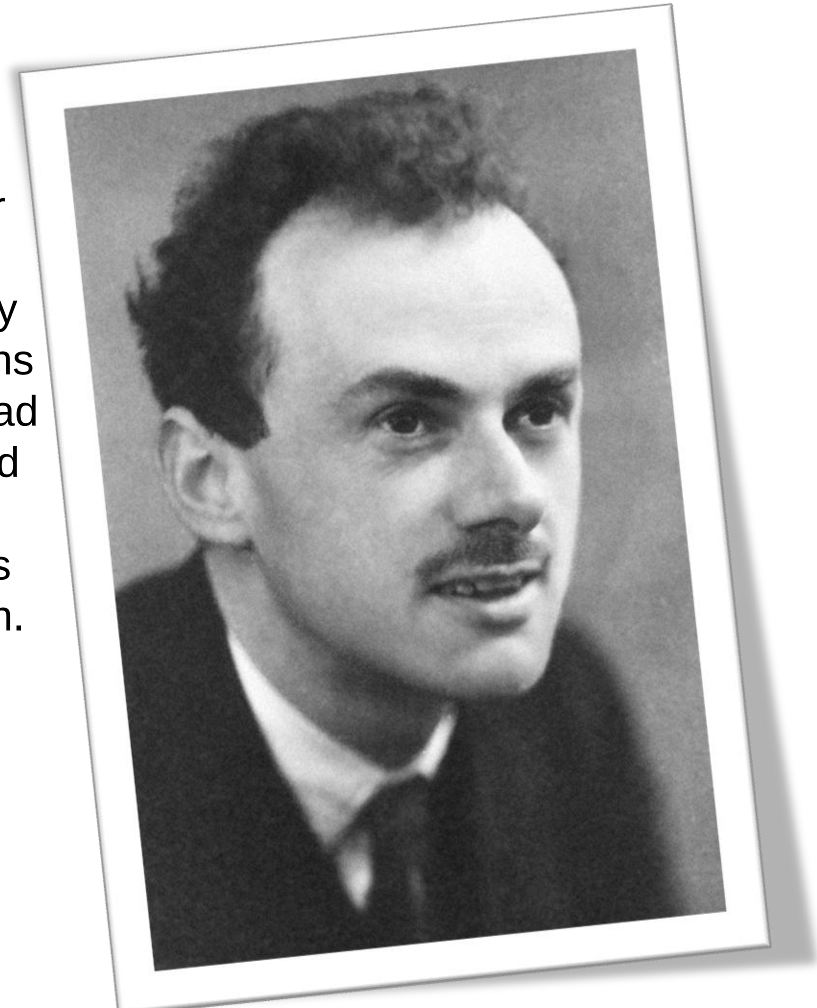
- Bohr's atom.

Introduction to Atomic Structure – Models



Erwin Schrödinger
1887 – 1961
Awarded the Nobel Prize for Physics in 1933.

- Schrödinger and Dirac mathematically treated electrons as *waves* instead of *particles* and formulated Schrödinger's Wave Equation.



Paul Dirac
1902 – 1984
Awarded the Nobel Prize for Physics in 1933.

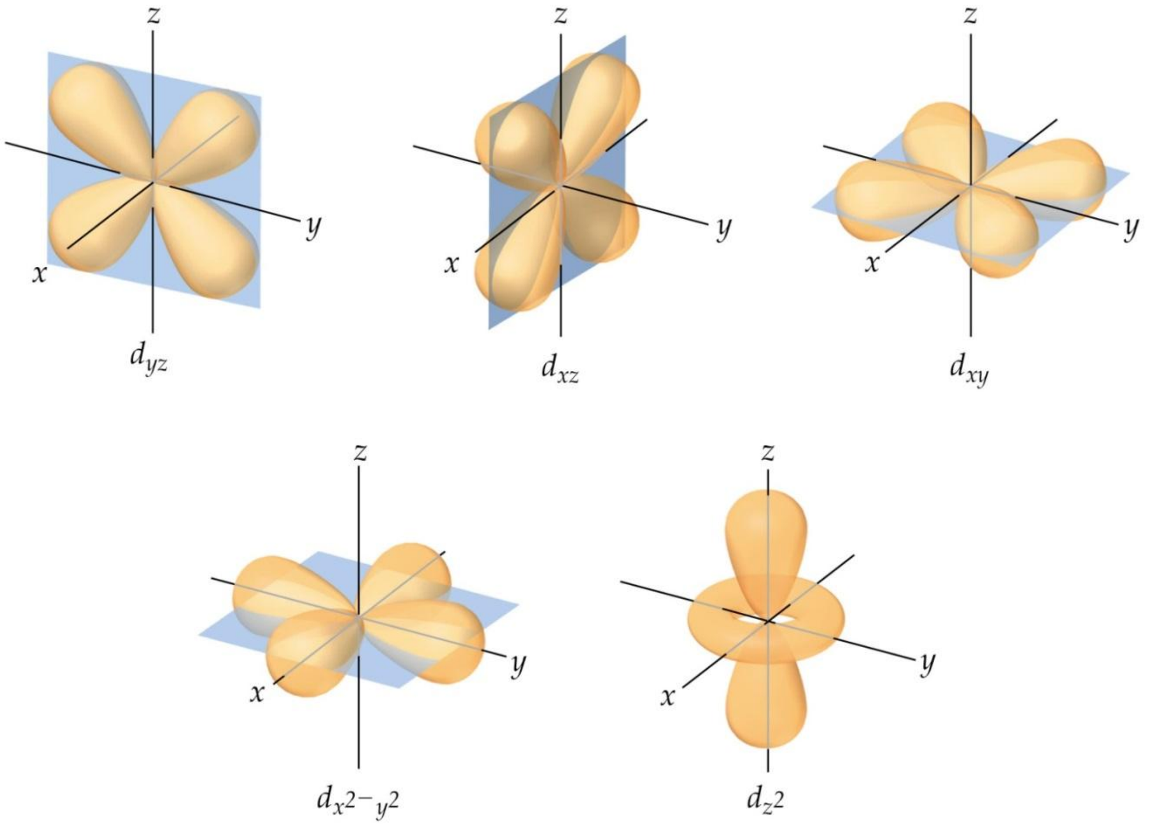
Introduction to Atomic Structure – Models

Schrödinger's Wave Equation

$$\frac{\delta^2 \Psi}{\delta x^2} + \frac{\delta^2 \Psi}{\delta y^2} + \frac{\delta^2 \Psi}{\delta z^2} + \frac{8m\pi^2}{h^2}(E - V)\Psi = 0$$

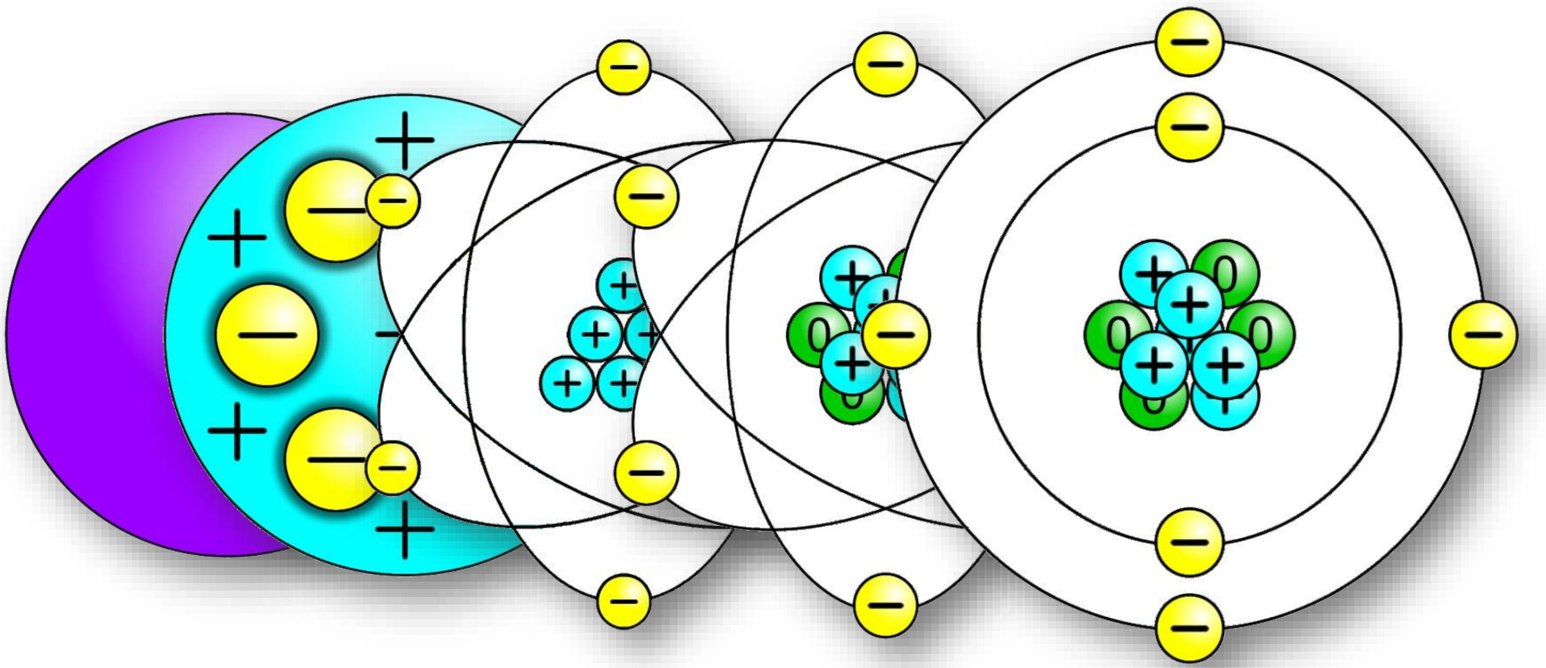
- Graphical solutions for this complex equation give rise to *electron orbitals* – the volume of space around the nucleus of an atom in which there is a high probability of finding an electron. Orbitals are not simply spherical, but can have some very strange shapes.

Introduction to Atomic Structure – Models



- Some of the graphical solutions to Schrödinger’s Wave Equation.

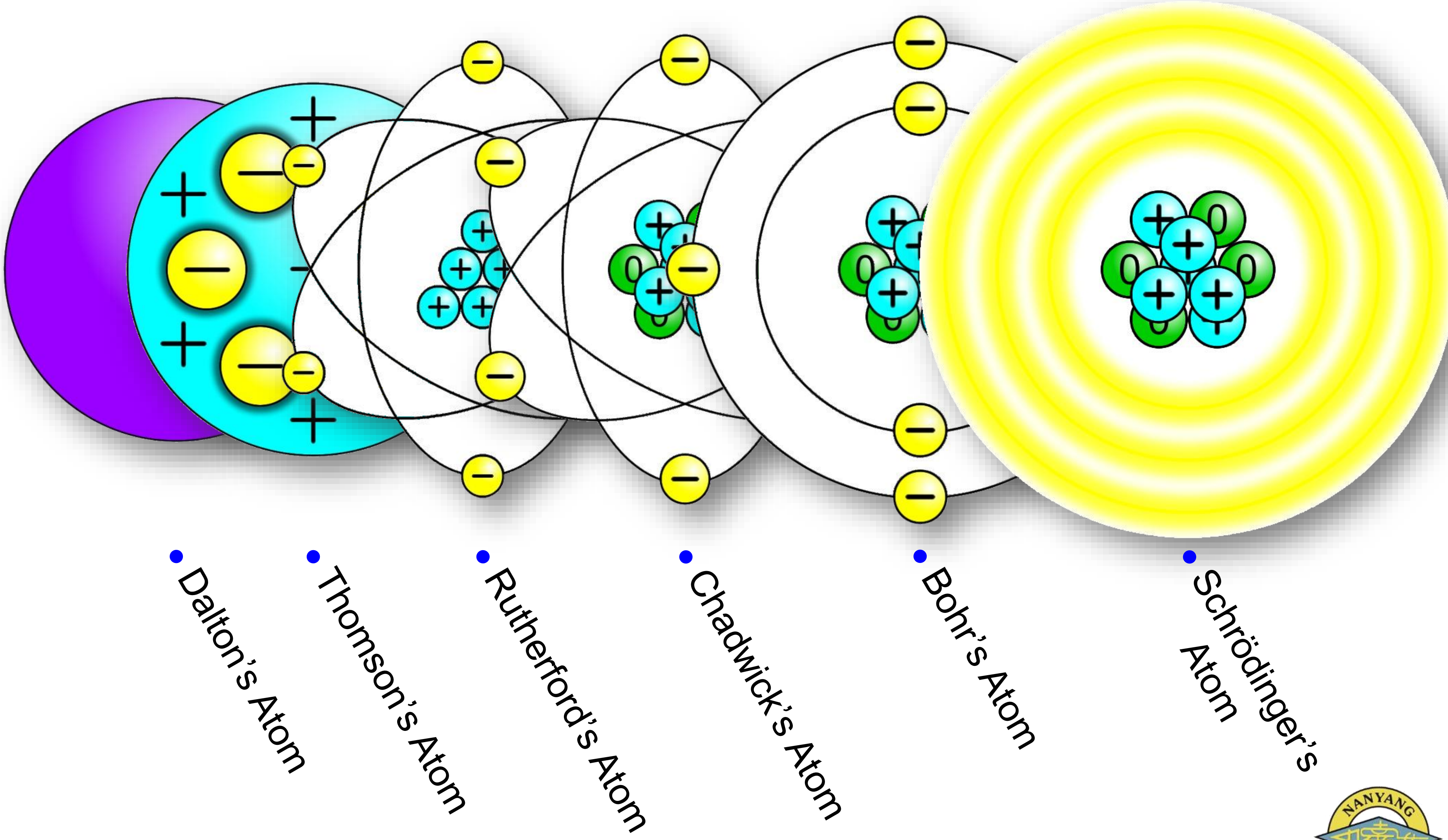
Introduction to Atomic Structure – Models



- Dalton's Atom
- Thomson's Atom
- Rutherford's Atom
- Chadwick's Atom
- Bohr's Atom

O Level Chemistry

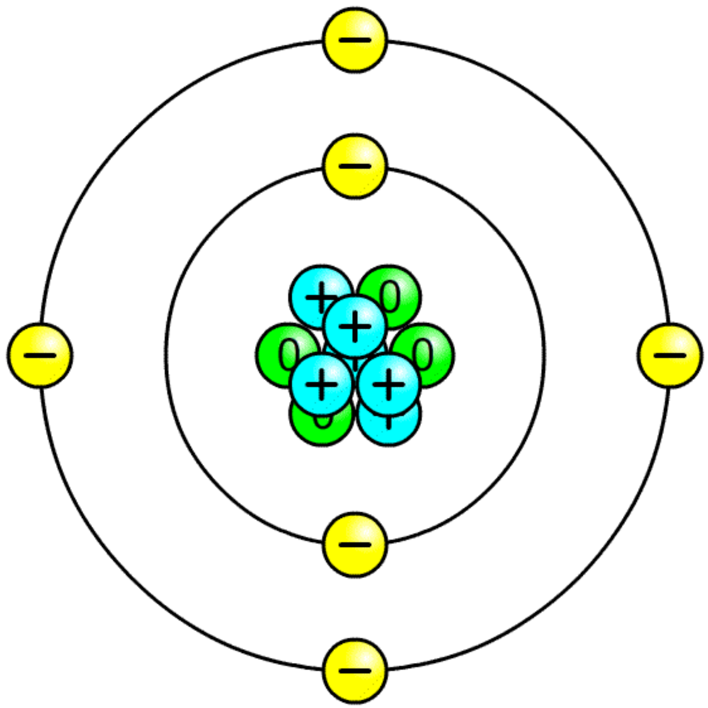
Introduction to Atomic Structure – Models



Introduction to Atomic Structure – Models

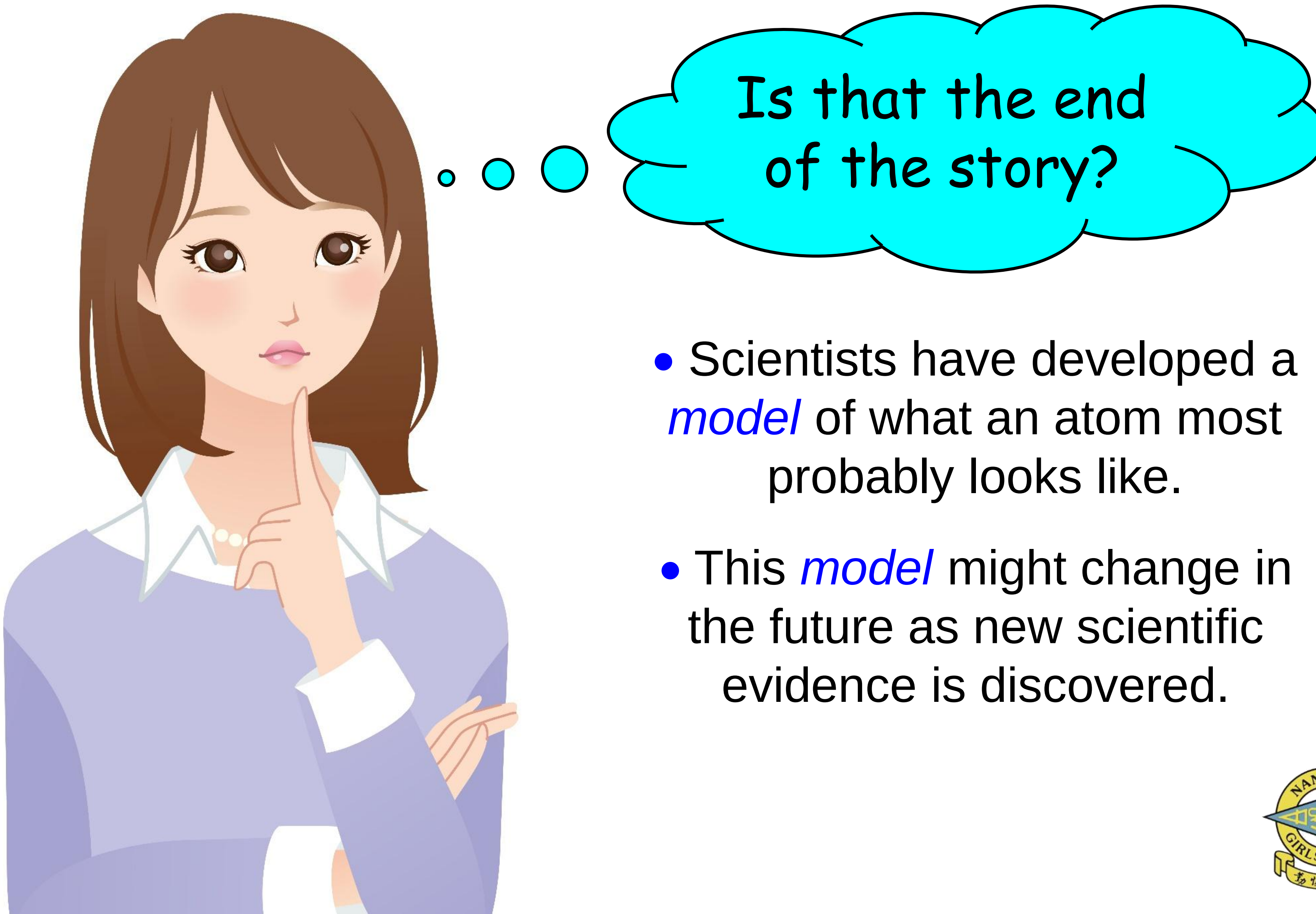
Summary: Modern Structure of the Atom for O' Level chemistry

- At the centre of the atom is a small, dense *nucleus* that is composed of *positively charged protons* (+1) and *neutral neutrons* (0).



- The *positive nucleus* of the atom is orbited by *negatively charged electrons* (–1). Electrons orbit the nucleus in *electron shells*.

Introduction to Atomic Structure – Models



- Scientists have developed a *model* of what an atom most probably looks like.
- This *model* might change in the future as new scientific evidence is discovered.

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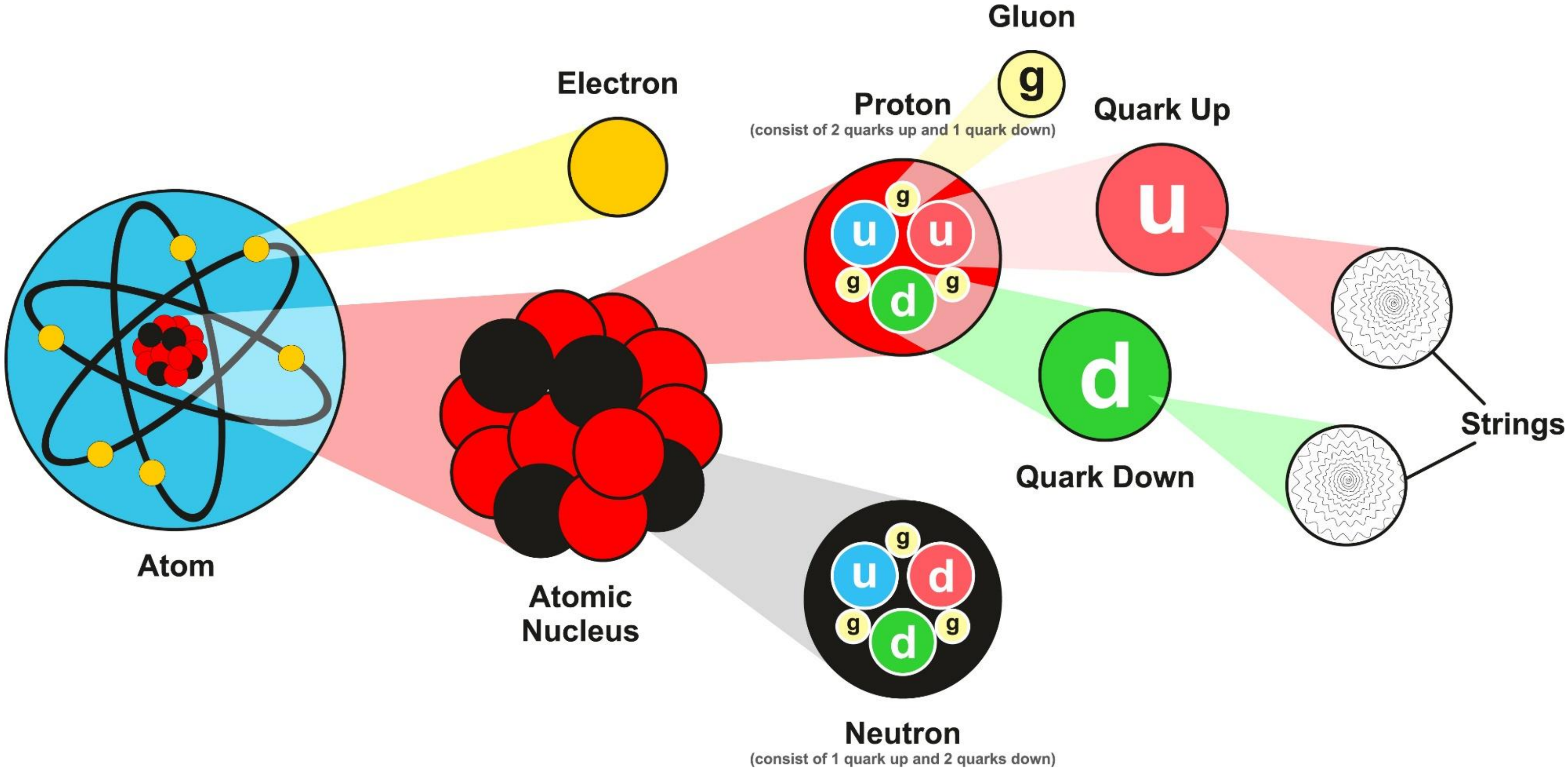

- Scientists think that protons and neutrons are made-up of even smaller particles called *quarks*, which may themselves be made-up of even smaller particles called *superstrings*.

Introduction to Atomic Structure – Models

What are some generalisations about models?

Introduction to Atomic Structure – Models

- Models simulate real world processes.
- Models facilitate testing and prediction.
- Models can be physical, conceptual or mathematical.
- Models simplify real world processes or behaviours.
- Models involve variables.
- Models have limitations.

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- Although an atom is too small to observe directly, Scientists have developed *conceptual models* (based upon empirical evidence obtained through experimental investigations) and *mathematical models* (*i.e.* Schrödinger's Wave Equation) that explain its structure to the best of human knowledge.

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Are there any abstract models to help me understand the structure of the atom?

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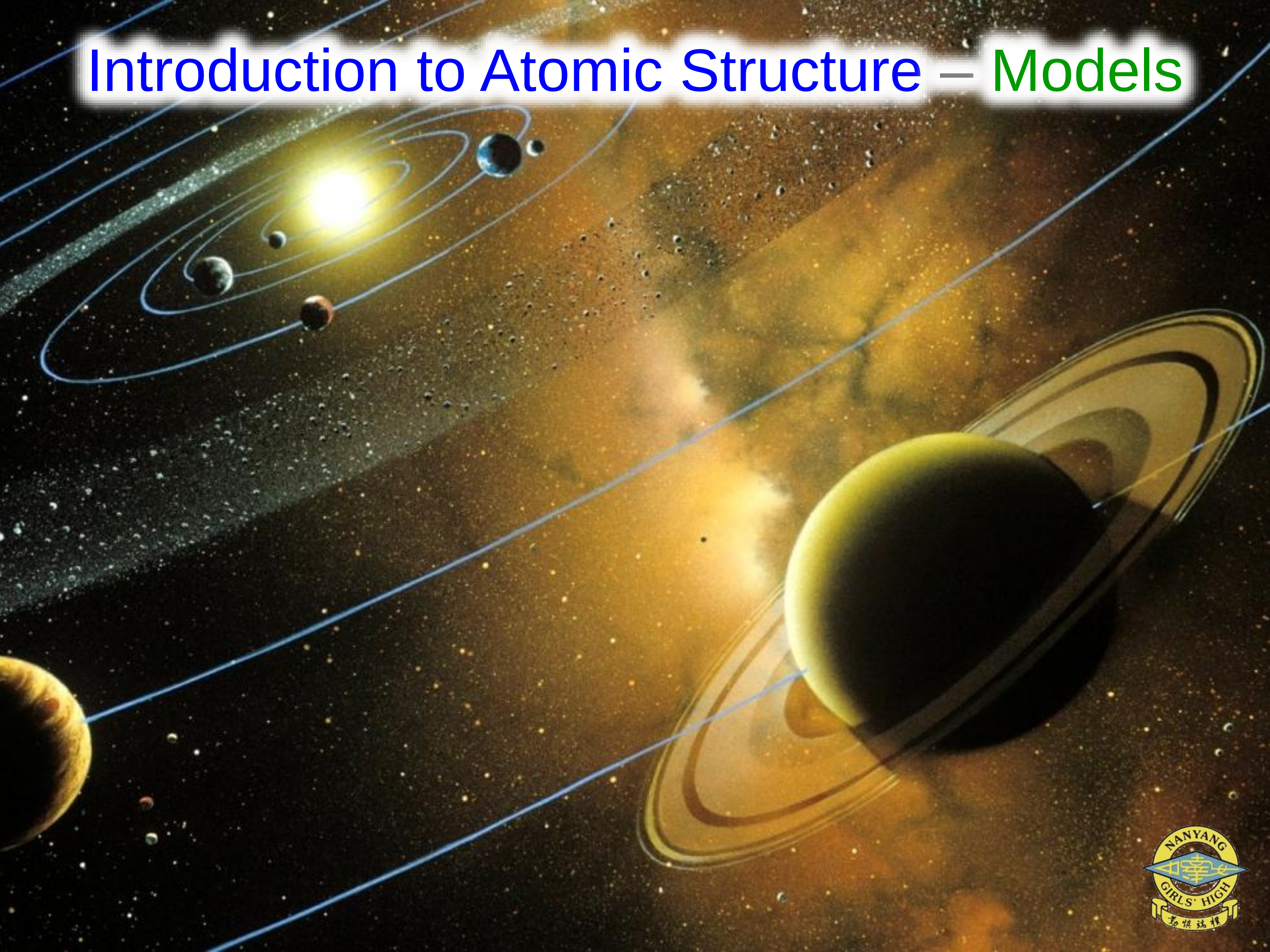

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- How can our solar system be used as a *model* to help us understand and remember the structure of the atom?

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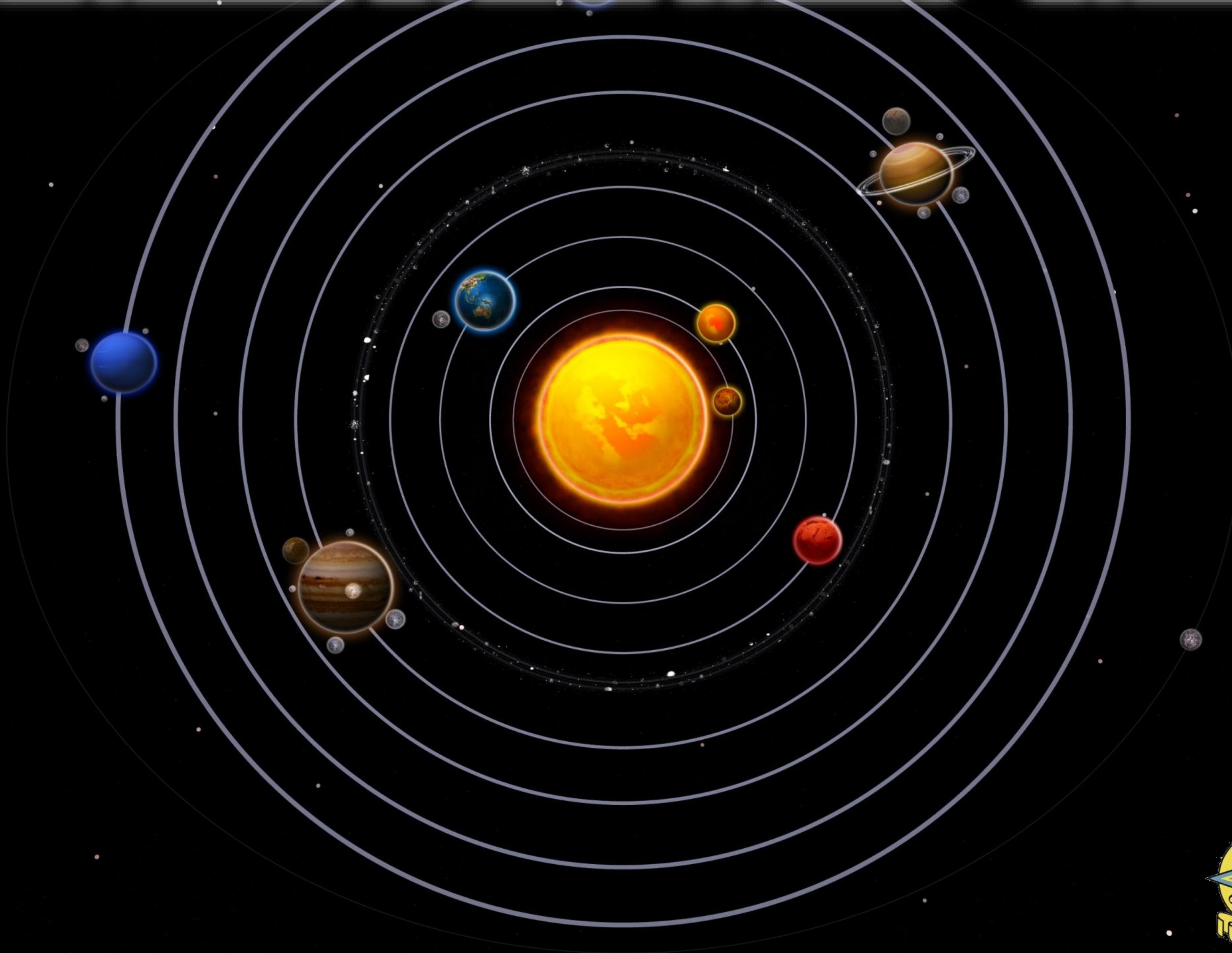

Introduction to Atomic Structure – Models

- Sun = Nucleus (small and dense at the centre).
- Planets = Electrons (orbiting the sun / nucleus).
- Just like the solar system, atoms are *mostly empty space*.
- What are the *limitations* of this *model* ?

Introduction to Atomic Structure – Models

What are some other examples of models?

- Models are often used by scientists in order to explain and investigate scientific concepts and phenomena.

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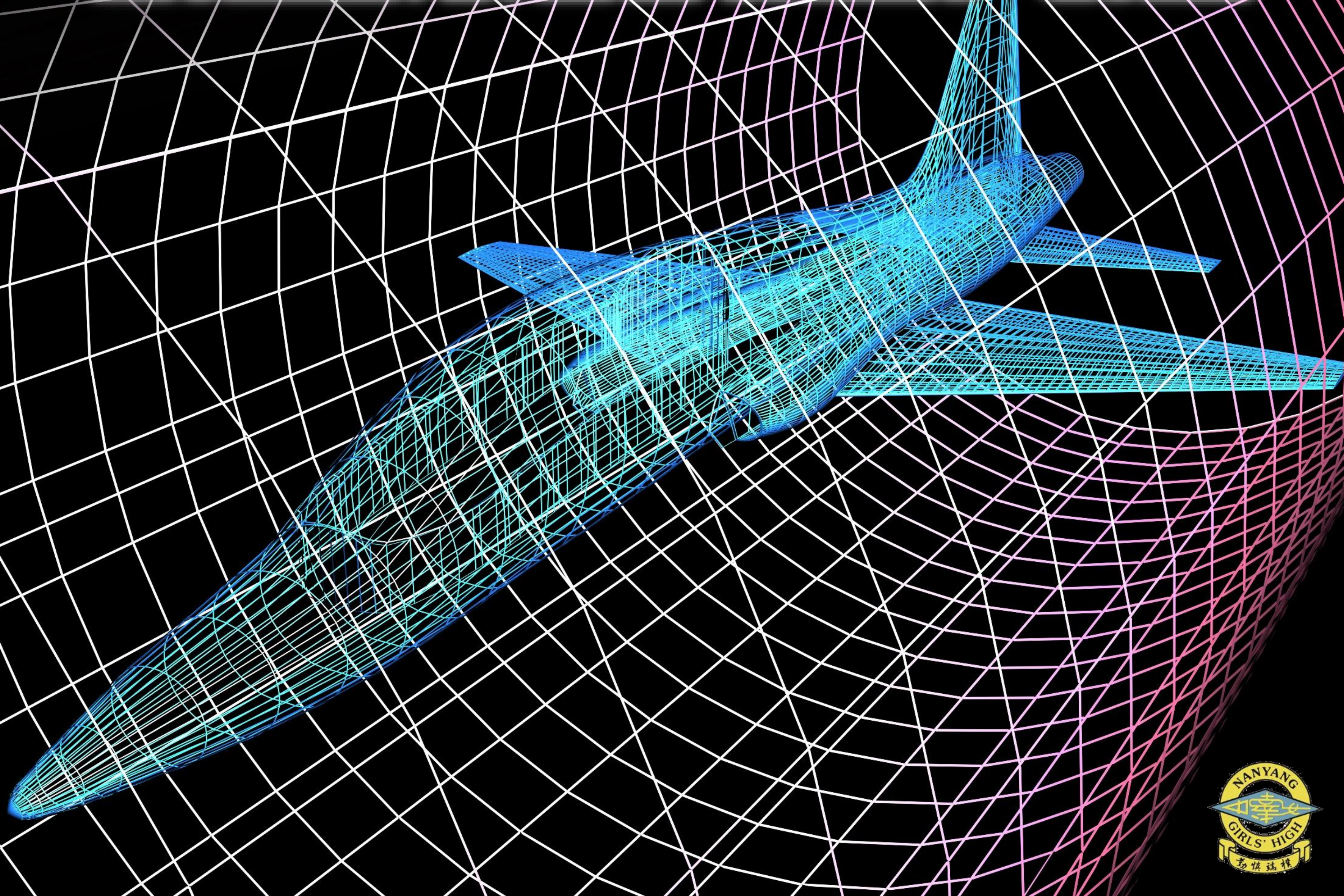

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- Mathematical models allow testing and prediction of an object's behaviour. This often requires a powerful computer and software to simulate how an object will behave under different conditions.
- Mathematical models can be used in conjunction with physical models.
- Mathematical models are useful tools for investigating phenomena that are very dangerous / difficult / expensive to create in a laboratory, *e.g.* modelling the spread of a virus or modelling a nuclear explosion.

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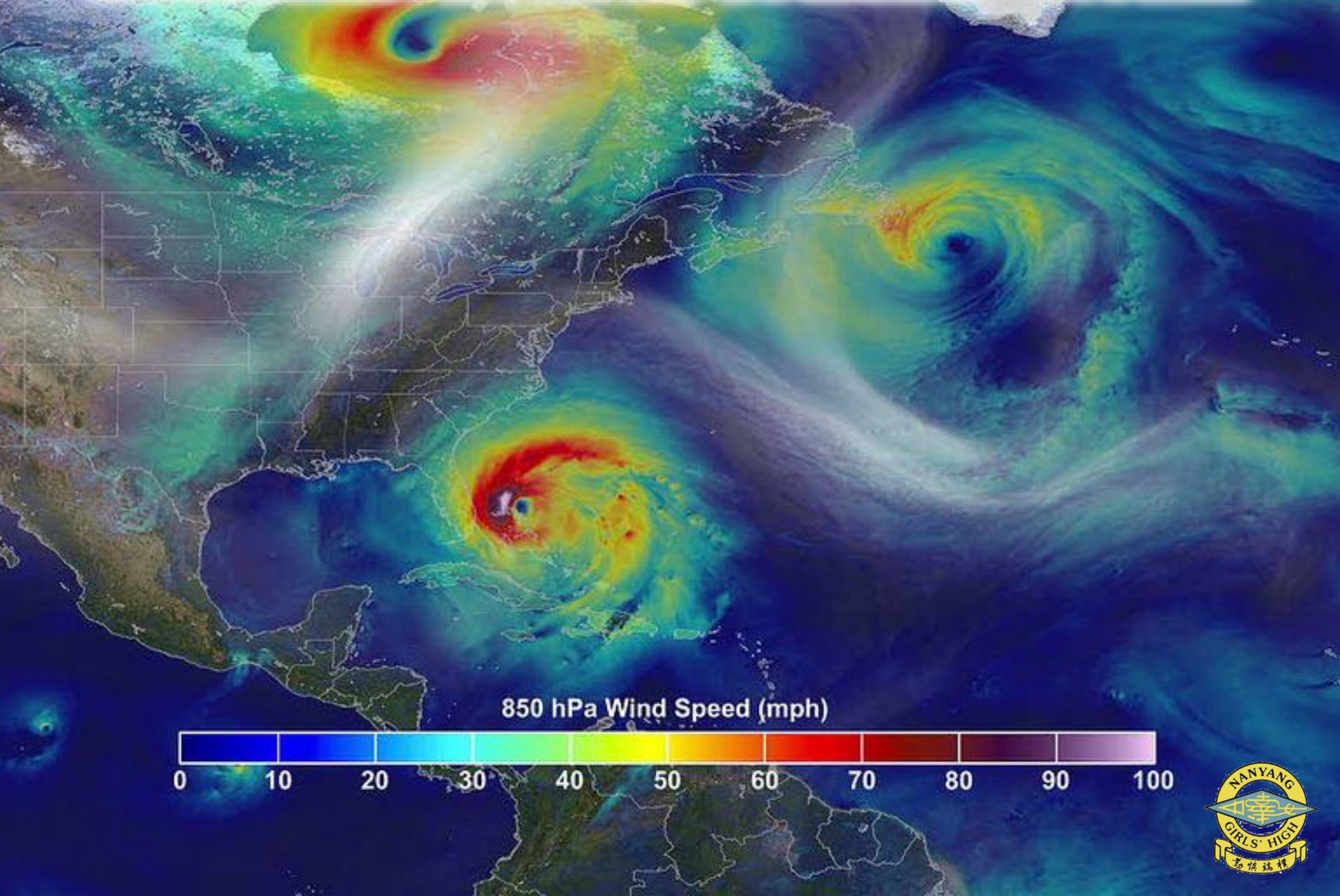

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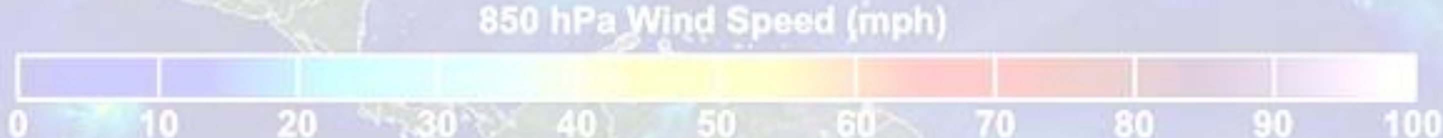
- Supercomputers are used to *model* extremely complex weather *systems* in order to *predict* their impact on human populations.

- Supercomputers are also used to *model* and *predict* important *changes* in the Earth's climate, such as increasing levels of carbon dioxide (a greenhouse gas) and its effect on global temperatures.



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- Physical models used in architecture help designers visualise the building's shape, size and space. Models also help designers see how the building interacts with light and shadow.
- Physical models help architects in the creative process by allowing them to visualise what happens as they experiment with different ideas.
- Physical models allow architects to visualise how a building is suited to its environment.

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NANYANG GIRLS' HIGH

Introduction to Atomic Structure – Models

- This photograph shows a university student testing a scale model of a car in a wind tunnel.
- This type of investigation allows scientists and engineers to examine the aerodynamic stability of the car. Similar experiments can be conducted on scale models of aircraft and ships.
- Based upon observations made when testing the model, the car's design can be modified before the actual car is manufactured, hence saving both time and money.

Introduction to Atomic Structure – Models

Introduction to Atomic Structure – Models

- In an age when vehicle design teams have supercomputers, 3D printing and virtual reality at their disposal, most car manufacturers still render actual size models of their prototypes in clay.

- Clay has three characteristics that make it suitable for motor vehicle design:

→ Clay is easy to change – it can be added to the model, taken away, and it is easy to mould.

→ Clay allows designers to be creative – creating and visualising their ideas quickly.

→ Clay is good for collaboration – designers can work together and brainstorm on the same model.

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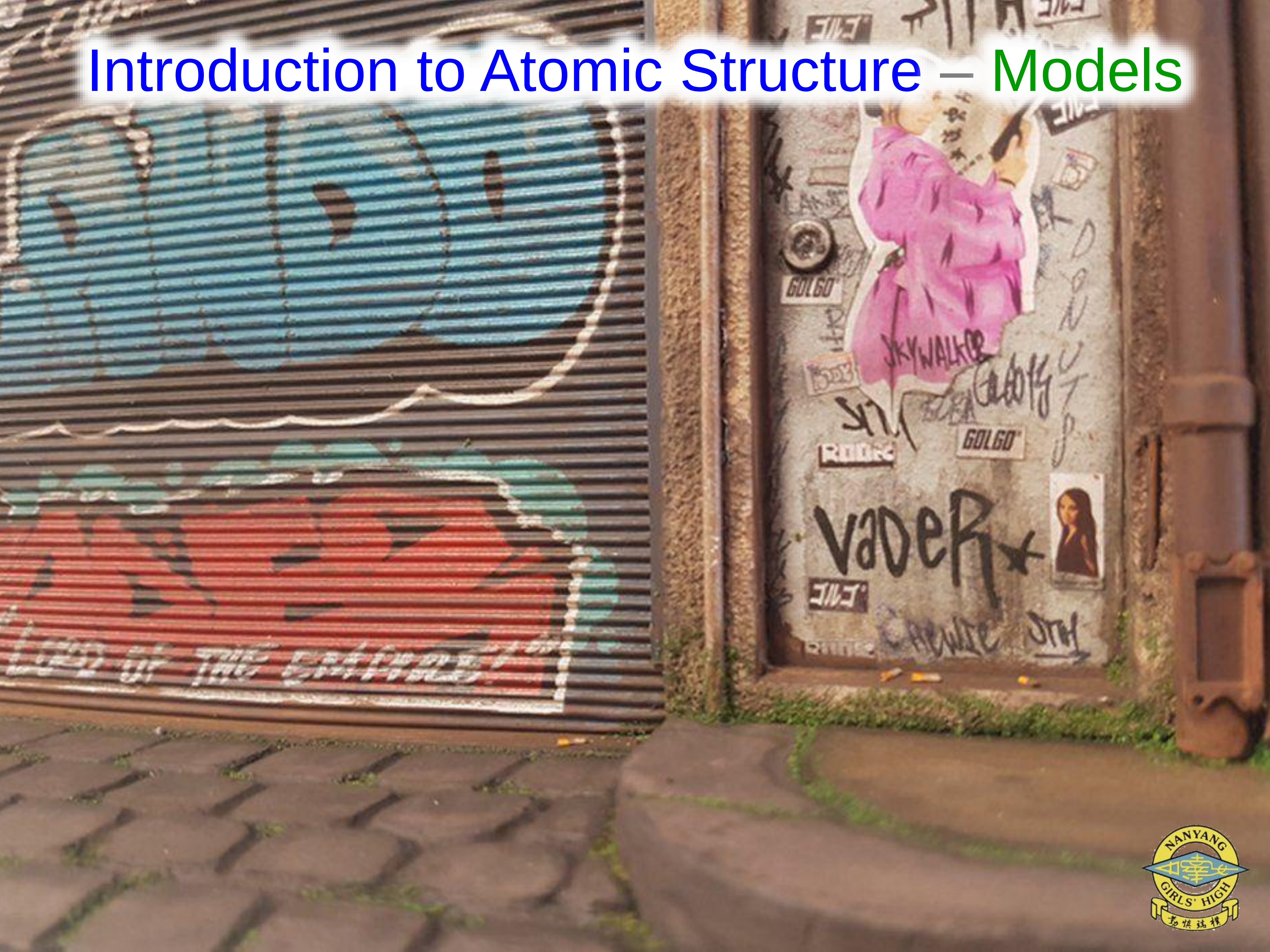

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- At first glance, this appears to be a photograph of a street in almost any Asian city.
- This is actually a *hyper-realistic model* created by the artist Joshua Smith.
- It reminds us that models are also important in Art, and that – when constructing a model in Art or Science – we strive to make the model as *accurate* as possible.

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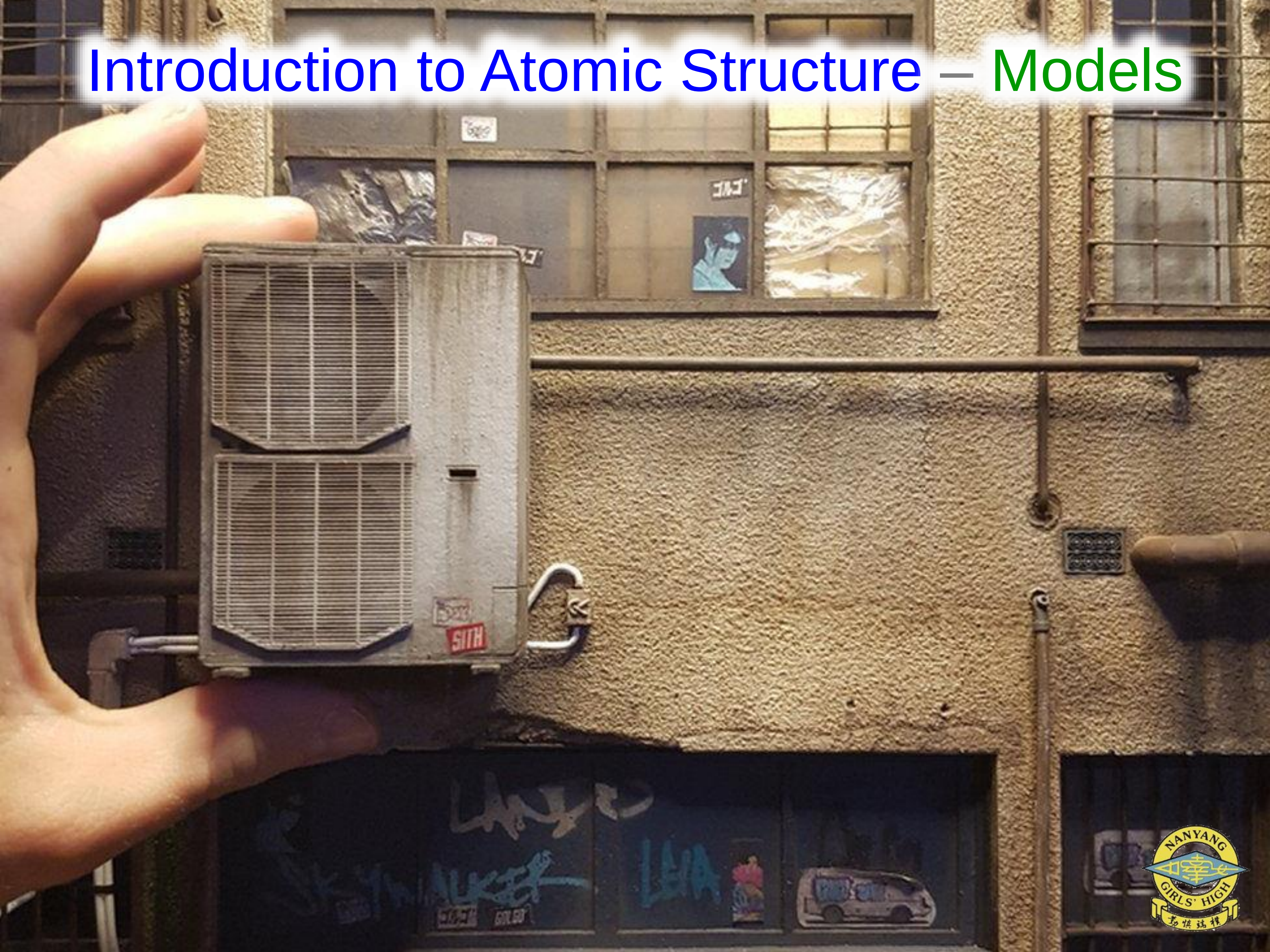

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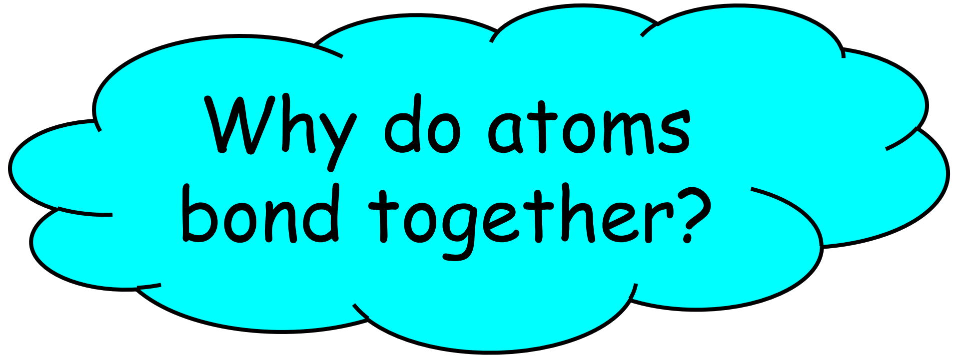

- That is another story…

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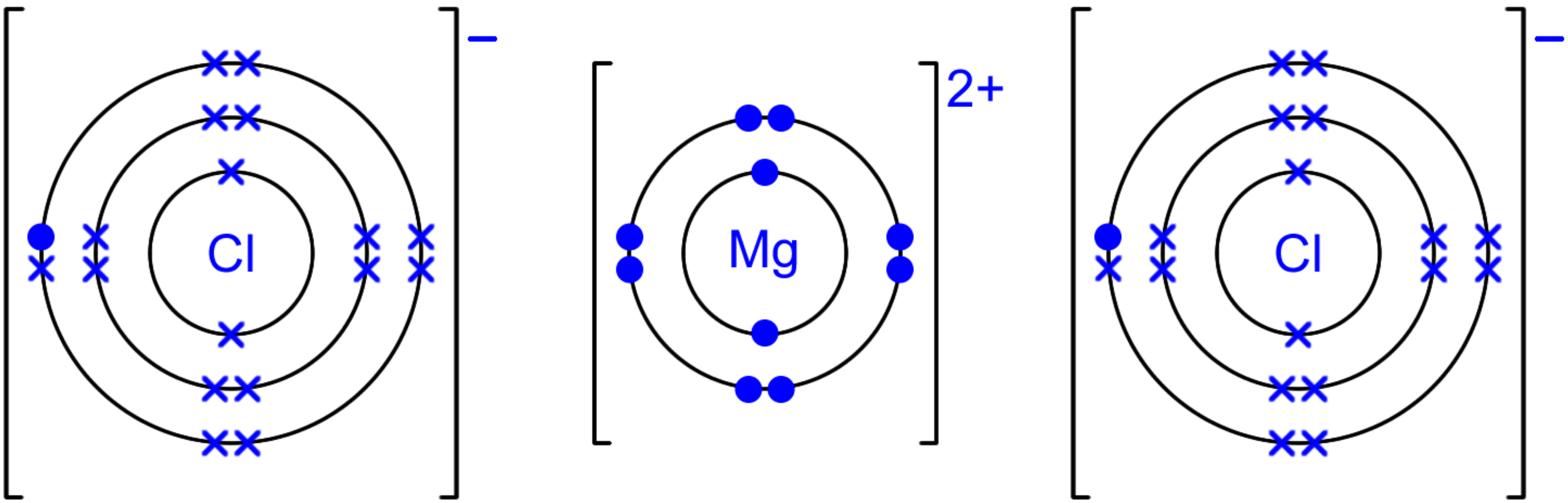
Ionic Bonding – Metal and Non-metal

Example – Magnesium Chloride, $MgCl_2$



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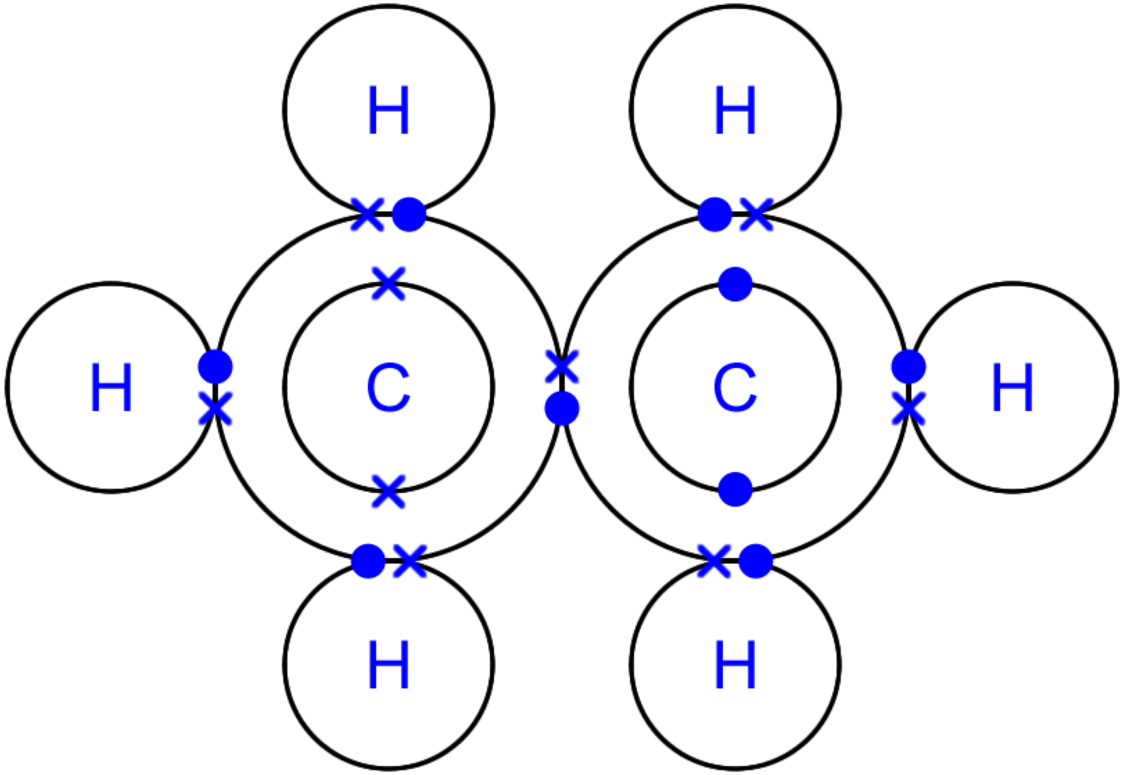
Covalent Bonding – Non-metal and Non-metal

Example – Ethane, C_2H_6



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- Useful Websites

→ Interactive animation* on atomic structure: www.chemical.sg

→ Interactive quiz* on atomic structure: www.learnchemistry.sg

*Requires Adobe Flash Player.
For devices that do not support Adobe Flash, download and install the Puffin web browser.

Introduction to Atomic Structure – Models

Presentation on
Introduction to Atomic Structure
by Dr. Chris Slatter
christopher_john_slatter@nygh.edu.sg

Nanyang Girls' High School
2 Linden Drive
Singapore
288683

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