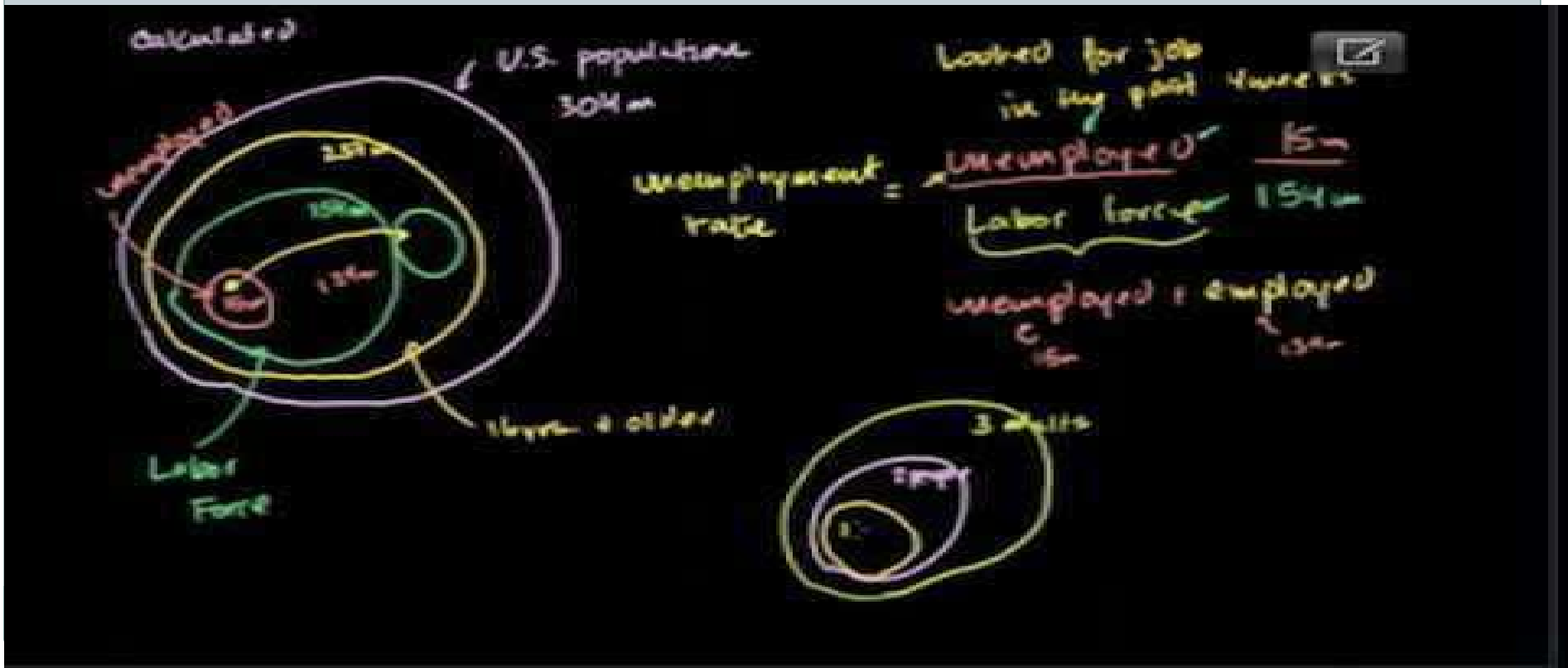
The Atom

A COMPLETE OVERVIEW

- (Optional) Recommended Link! Khan Academy Introduces the Atom.
- 21 minutes
- http://www.khanacademy.org/video/introduction-to-the-atom?playlist=Chemistry



Defining the Atom

- All matter is composed of atoms
- Atoms are the smallest particle of an element that retains its identity in a chemical reaction.
- Atom comes from the Greek word “atomos” meaning indivisible.

History of the Atom

EVOLUTION OF THE ATOMIC THEORY

DALTON

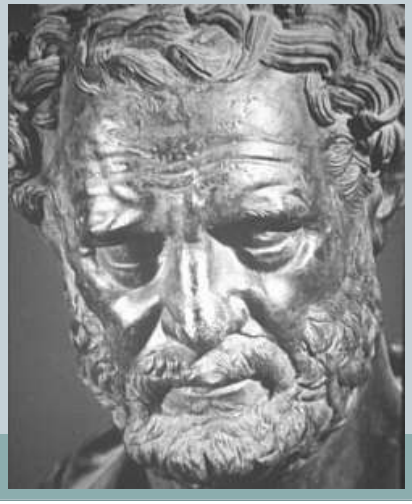
THOMPSON

RUTHERFORD

BOHR

Democritus

- Democritus (460 BC – 370 BC) was among the 1st to suggest the existence of atoms.
- Democritus believed that atoms were indivisible and indestructible.
- His approached was not based on scientific method and was not accepted until later scientific theory.



ATOMA

(GREEK FOR INDIVISIBLE)

Dalton's Atomic Theory

- The modern atomic thought began with John Dalton (1766-1844)
- Dalton used experimental method to transform Democritus's idea of atoms into a scientific theory.
- Dalton studied the ratios in which elements combine and the result was Dalton's atomic theory.

Atomic Theory

- In 1808 John Dalton proposed atomic theory.
- Dalton's theory explained several laws known at the time.
  - Law of conservation of matter
  - Law of definite proportions
  - Law of multiple proportions

Dalton's Atomic Theory (1808)

1. Elements are made of tiny particles called atoms.
2. Atoms of a given element are identical.
3. Atoms of different elements differ from each other in some fundamental way.

Dalton's Atomic Theory (1808)

4. Atoms of one element can join with atoms of other elements to form compounds.
   - A given compound is always made of the same elements combined in the same ways.
     - Explains the law of multiple proportions and the law of definite composition.

Dalton's Atomic Theory (1808)

5. Atoms are indivisible in chemical reactions.
   - Chemical reactions change how atoms are grouped (bonded) together.
     - Explains the law of conservation of matter.

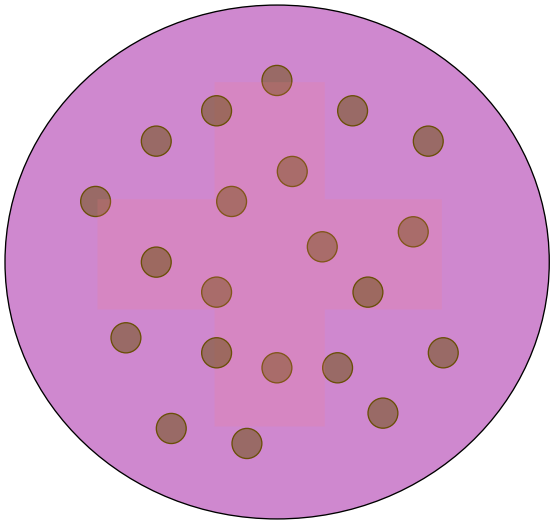
Electrons

- Discovered in 1897 by J.J. Thomson (1856-1940) an English physicist.
- They are negatively charged subatomic particles.
- Thomson performed experiments using a sealed glass tube with gases in it. He passed an electric current through the tube and the result was a cathode ray.

HISTORY OF THE ATOM

1904

Thompson develops the idea that an atom was made up of electrons scattered unevenly within an elastic sphere surrounded by a soup of positive charge to balance the electron's charge



PLUM PUDDING MODEL

like plums surrounded by pudding.

Electrons Continued

- U.S. physicist Robert A. Millikan (1868-1953) carried out experiments to find the quantity of charge carried out by an electron.
- He calculated the mass of the electron; that is very similar to the excepted mass given today.

Protons

- Eugen Goldstein (1850-1930) observed in 1886 that in a cathode-ray tube there were rays going in the opposite direction. He concluded they were positively charged particles.
- Protons are positively charged subatomic particles.
- Each proton has a mass about 1840 times that of an electron.

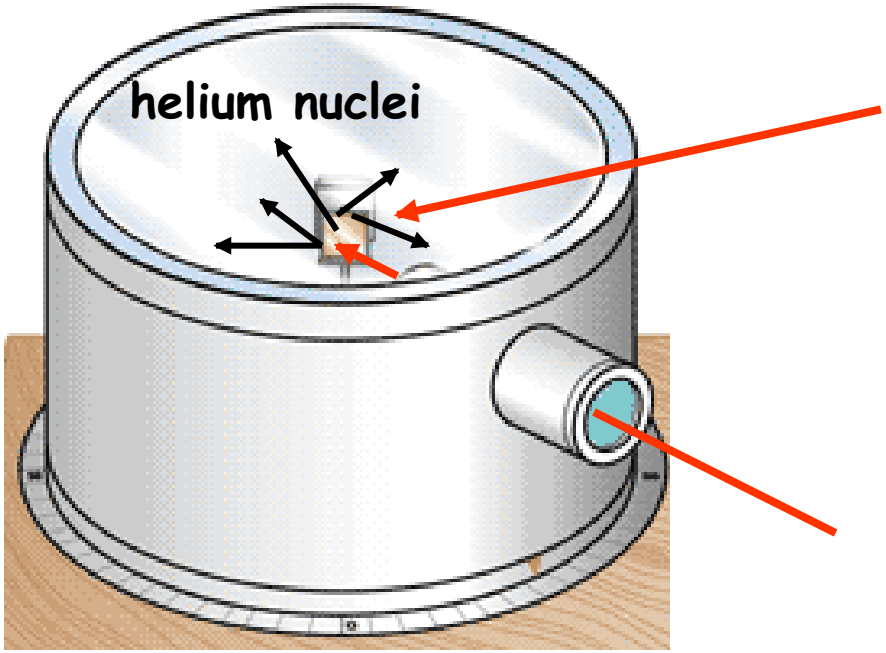
Neutrons

- In 1932 English physicist James Chadwick (1891-1974) confirmed the existence of another subatomic particle.
- Neutrons are subatomic particles with no charge but a mass nearly equal to the proton.

Rutherford's Gold-Foil Experiment

- This experiment change the prevailing thought of the structure of the atom.
- Because of this experiment Rutherford concluded that most the of alpha particles pass through because the atom is mostly empty space, and the reason that some of the particles were deflected were due to the concentration of the positive charge in the atom which is now known as the nucleus.

HISTORY OF THE ATOM



They found that while most of the helium nuclei passed through the foil, a small number were deflected and, to their surprise, some helium nuclei bounced straight back.

HISTORY OF THE ATOM

Rutherford's new evidence allowed him to propose a more detailed model with a **central nucleus**.

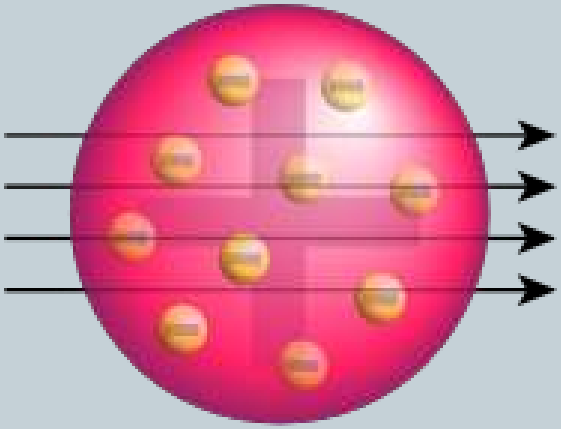
He suggested that the **positive charge** was all in a central nucleus. With this holding the electrons in place by electrical attraction

Structure of the atom

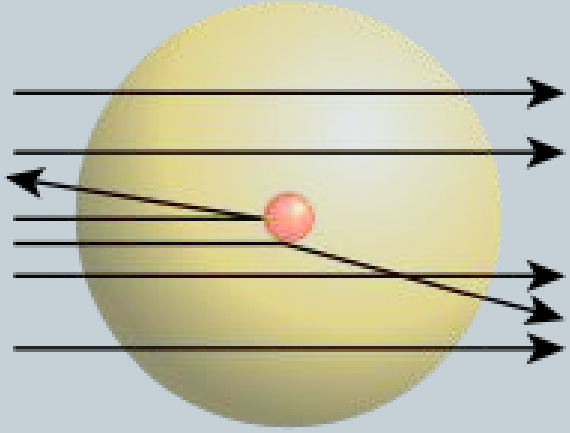
- The nucleus of the atom is the tiny central core of an atom and is composed of protons and neutrons.
- Rutherford's model is the nuclear atom: In the nuclear atom, the proton and neutron are located in the nucleus. The electrons are distributed around the nucleus.

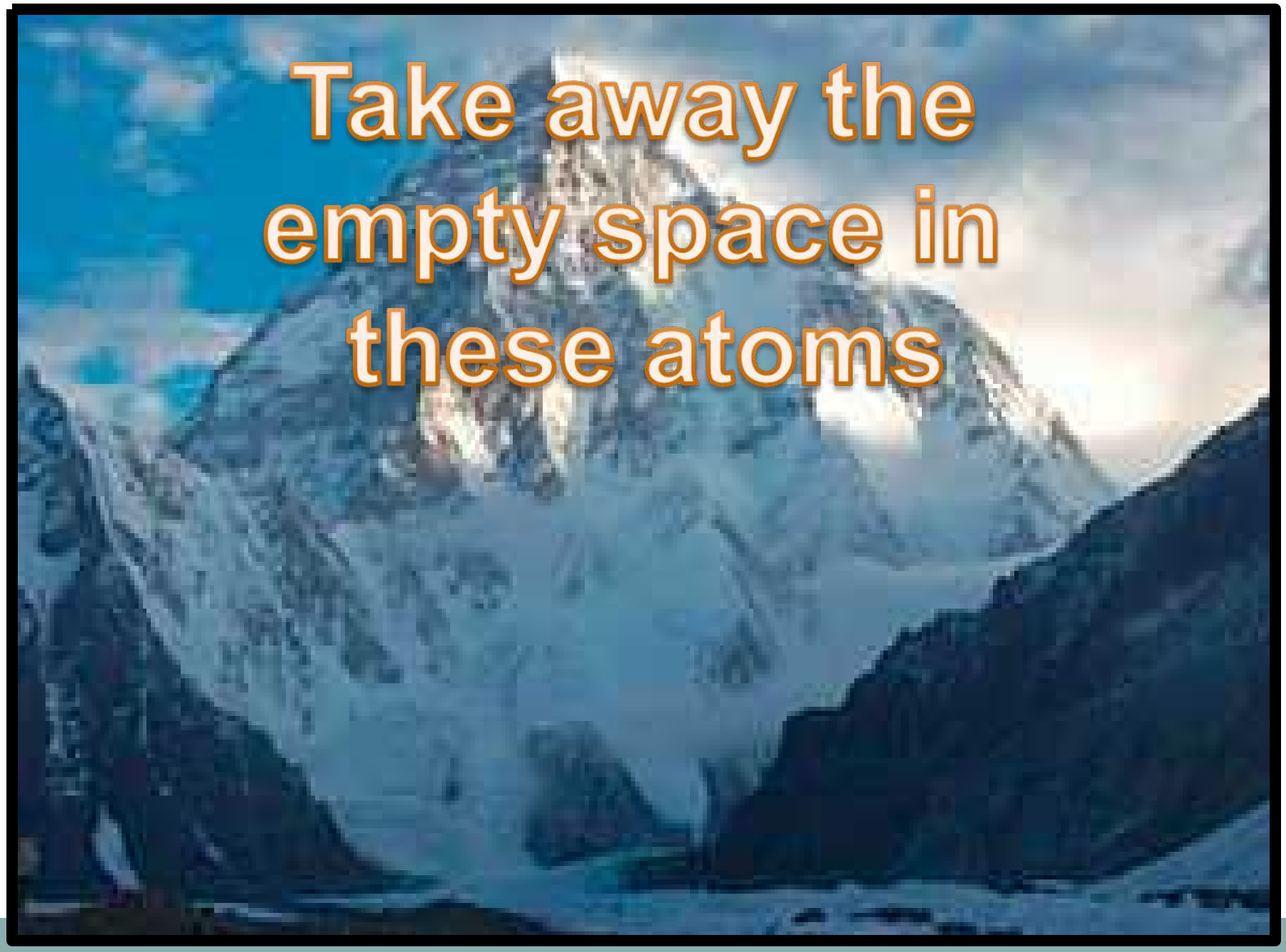
A New Model of the Atom

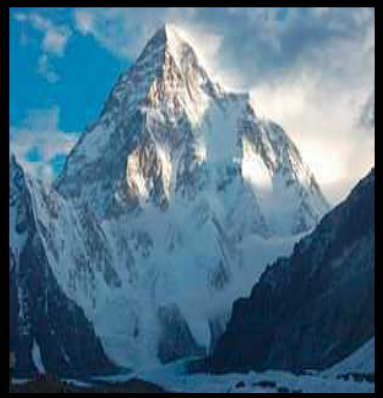
Expected based on
Plum pudding model



Rutherford's model
Based on "his" results




Take away the
empty space in
these atoms



The mountain could fit in a jug.

Everything is made chiefly of…

NOTHING

HISTORY OF THE ATOM

1913 Niels Bohr

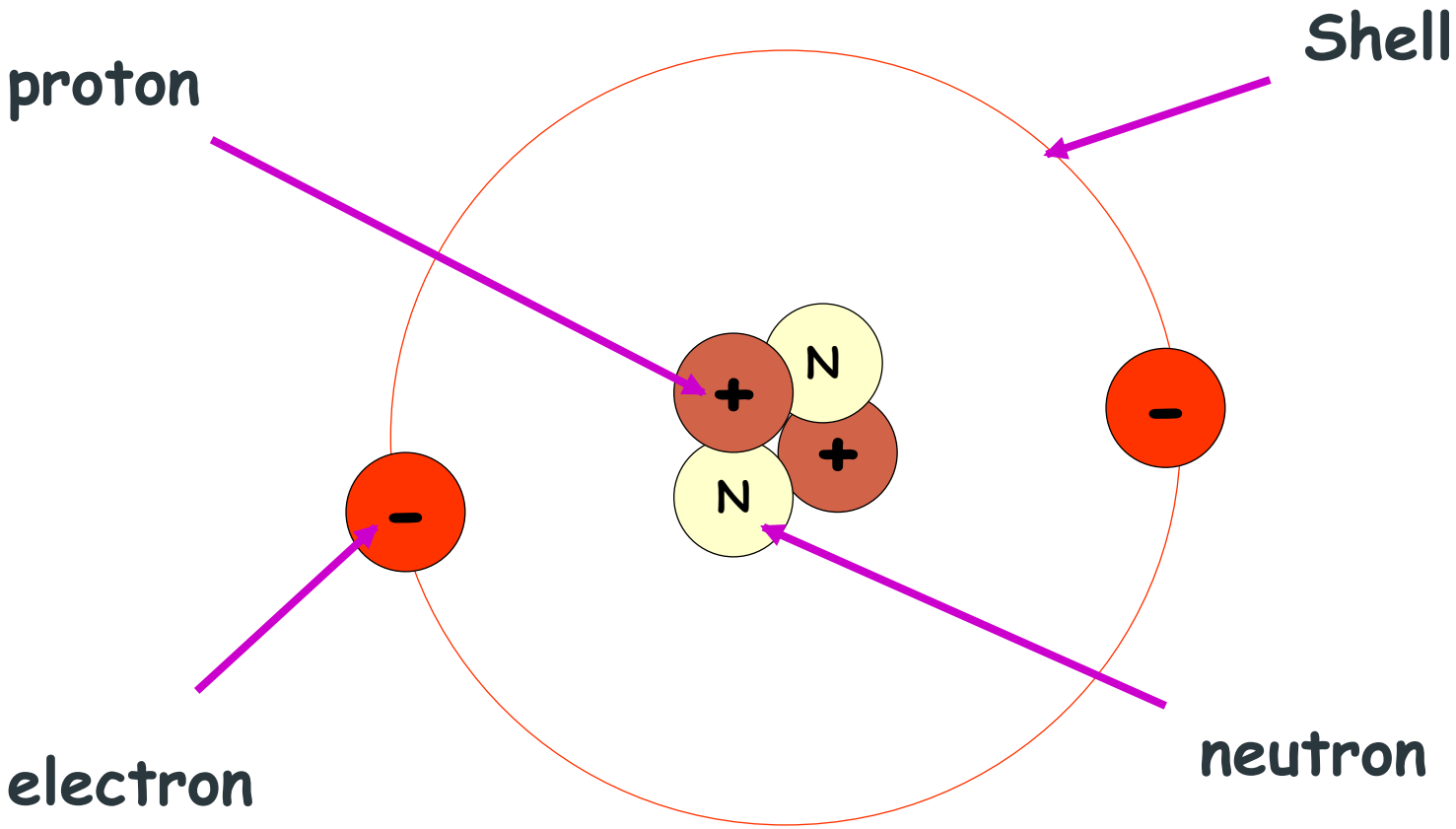
studied under Rutherford at the Victoria University in Manchester.

Bohr refined Rutherford's idea by adding that the electrons were in **orbits**. Rather like planets orbiting the sun. With each orbit only able to contain a set number of electrons.

Bohr's Atom

electrons in orbits

nucleus

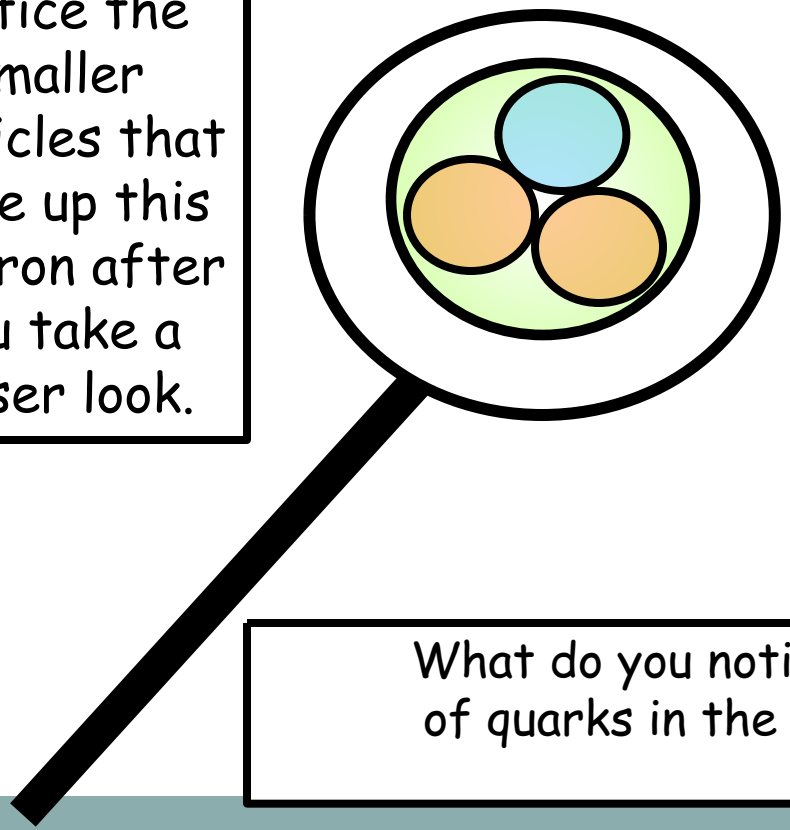


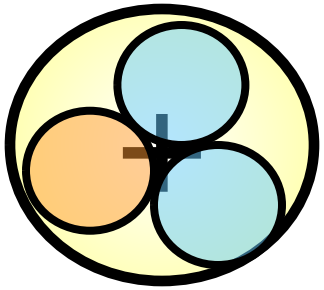
What do these particles consist of?

QUARKS

- Particles that make up protons and neutrons

Notice the smaller particles that make up this neutron after you take a closer look.



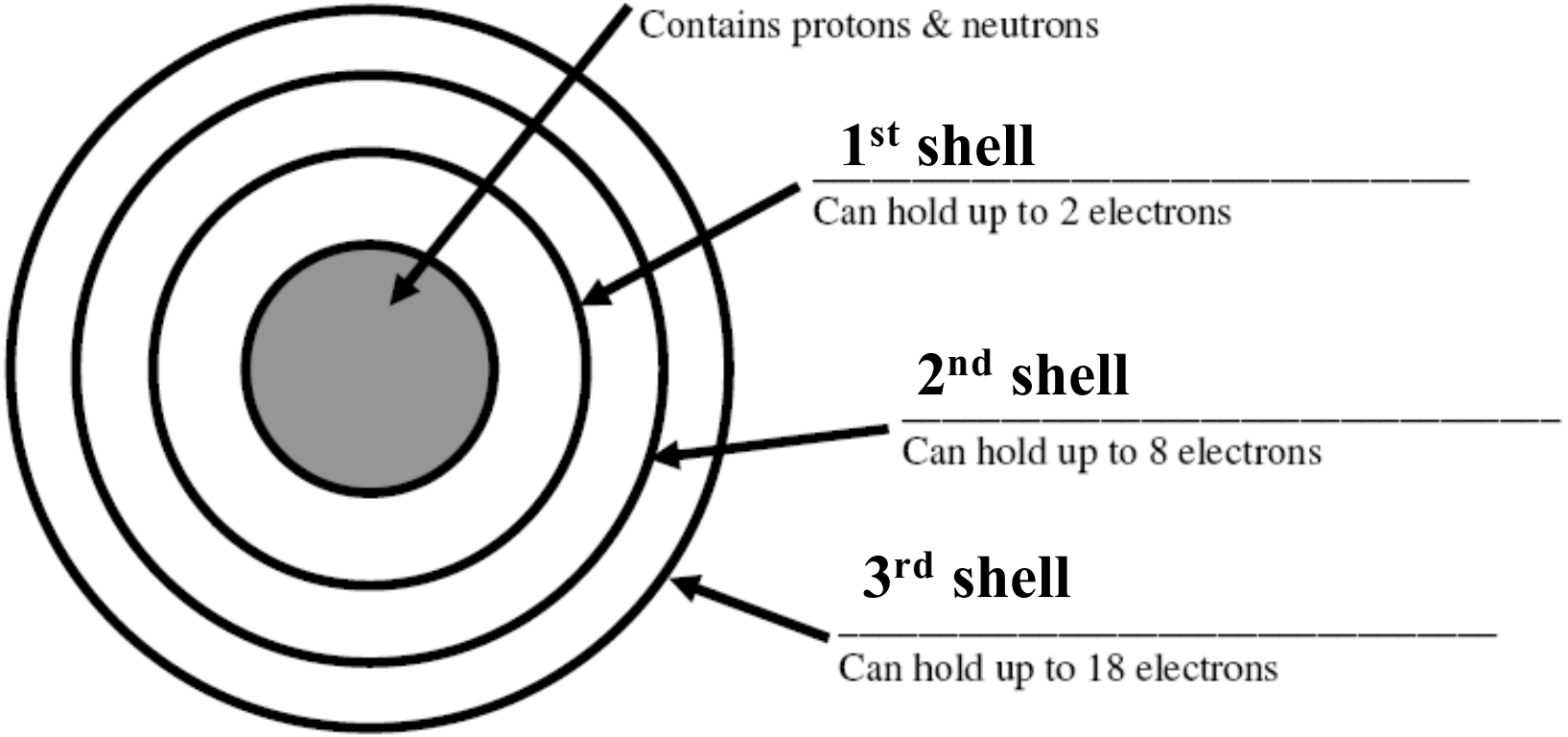


Notice the smaller particles that make up this proton after you take a closer look.

What do you notice about the number of quarks in the neutron and proton?

Electrons have special rules….

- You can't just shove all of the electrons into the first orbit of an electron.
- Electrons live in something called shells or energy levels.
- Only so many can be in any certain shell.
- The electrons in the outer most shell of any element are called **valance electrons**.

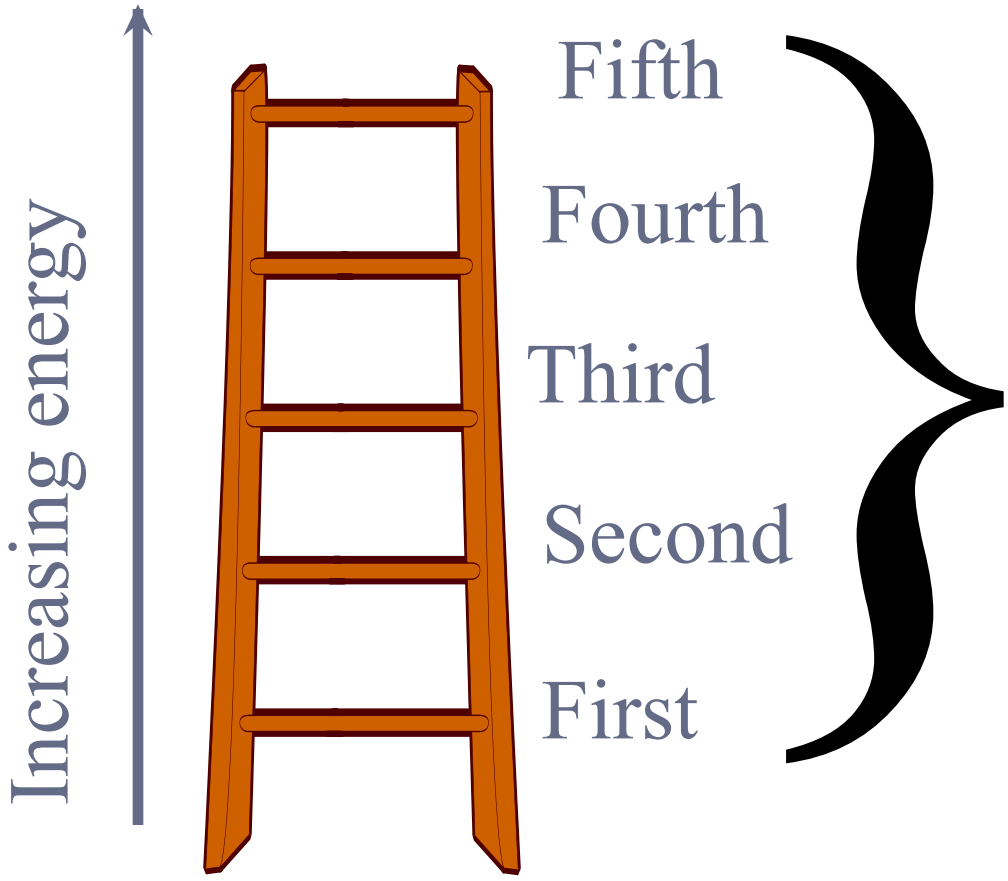


Adapted from http://www.sciencespot.net/Media/atomsfam.pdf

Bohr postulated that:

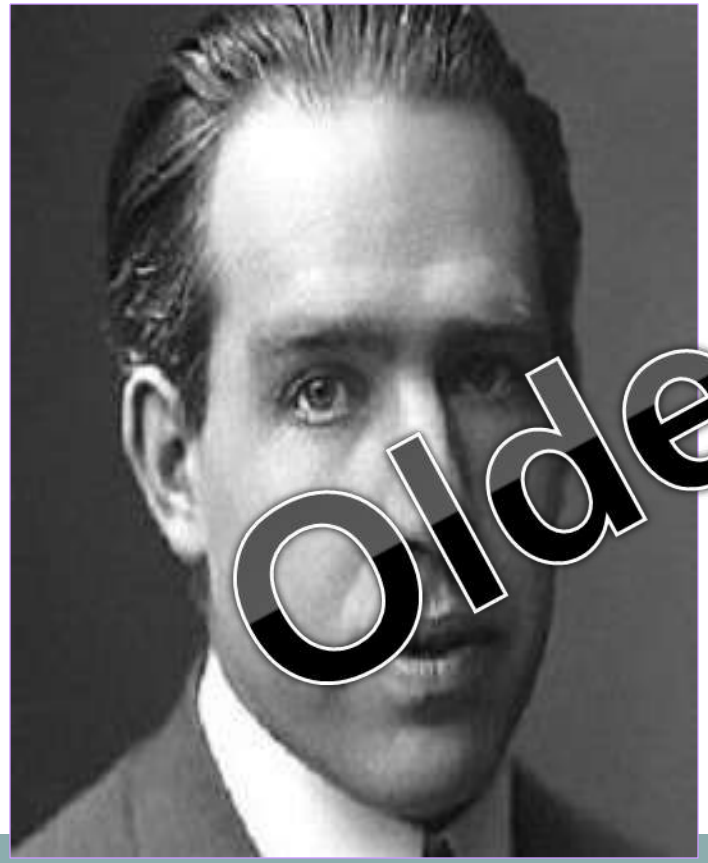
- Fixed energy related to the orbit
- Electrons cannot exist between orbits
- The higher the energy level, the further it is away from the nucleus
- An atom with maximum number of electrons in the outermost orbital energy level is stable (unreactive)

Energy Levels

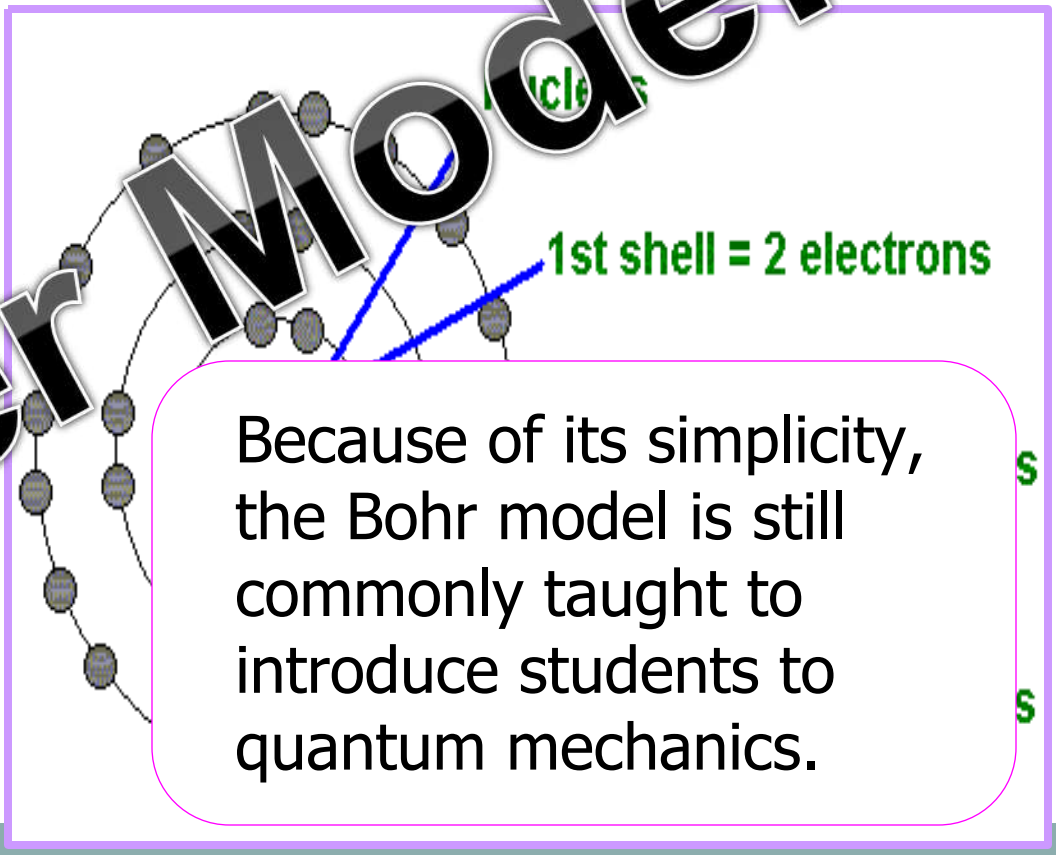


- Further away from the nucleus means more energy.
- There is no “in between” energy
- Energy Levels

- Neils Bohr Model (1913): Depicts the atom as a small, positively charged nucleus surrounded by electrons that travel in circular orbits around the nucleus



Older Model

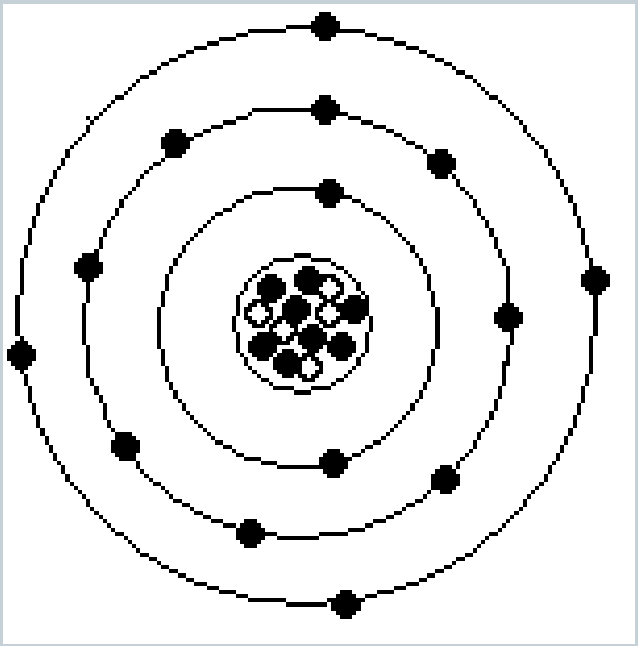


Because of its simplicity, the Bohr model is still commonly taught to introduce students to quantum mechanics.

What is the structure of an atom?

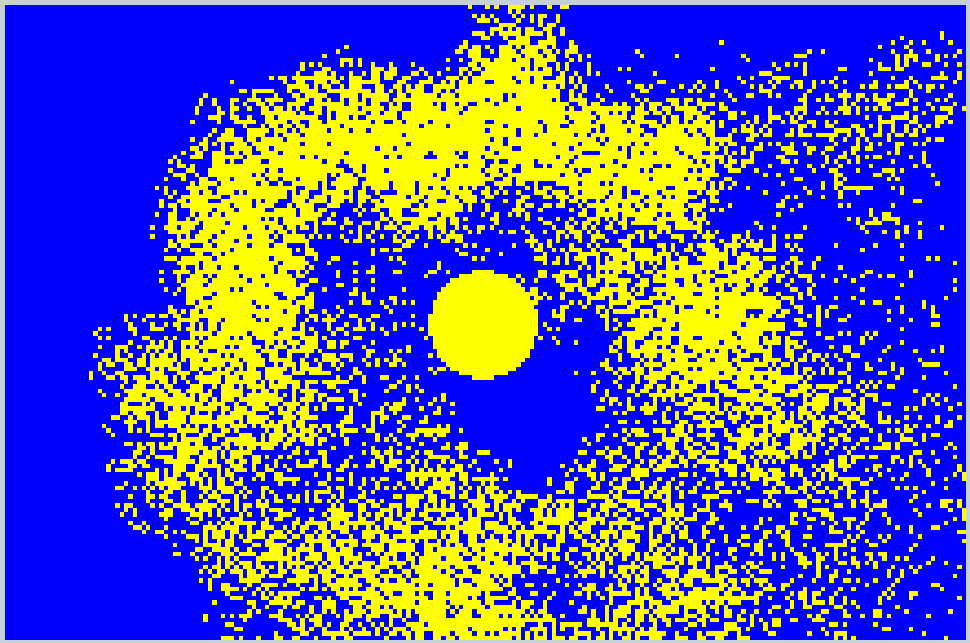
Bohr Model

"Planetary Model"



Schrödinger Model

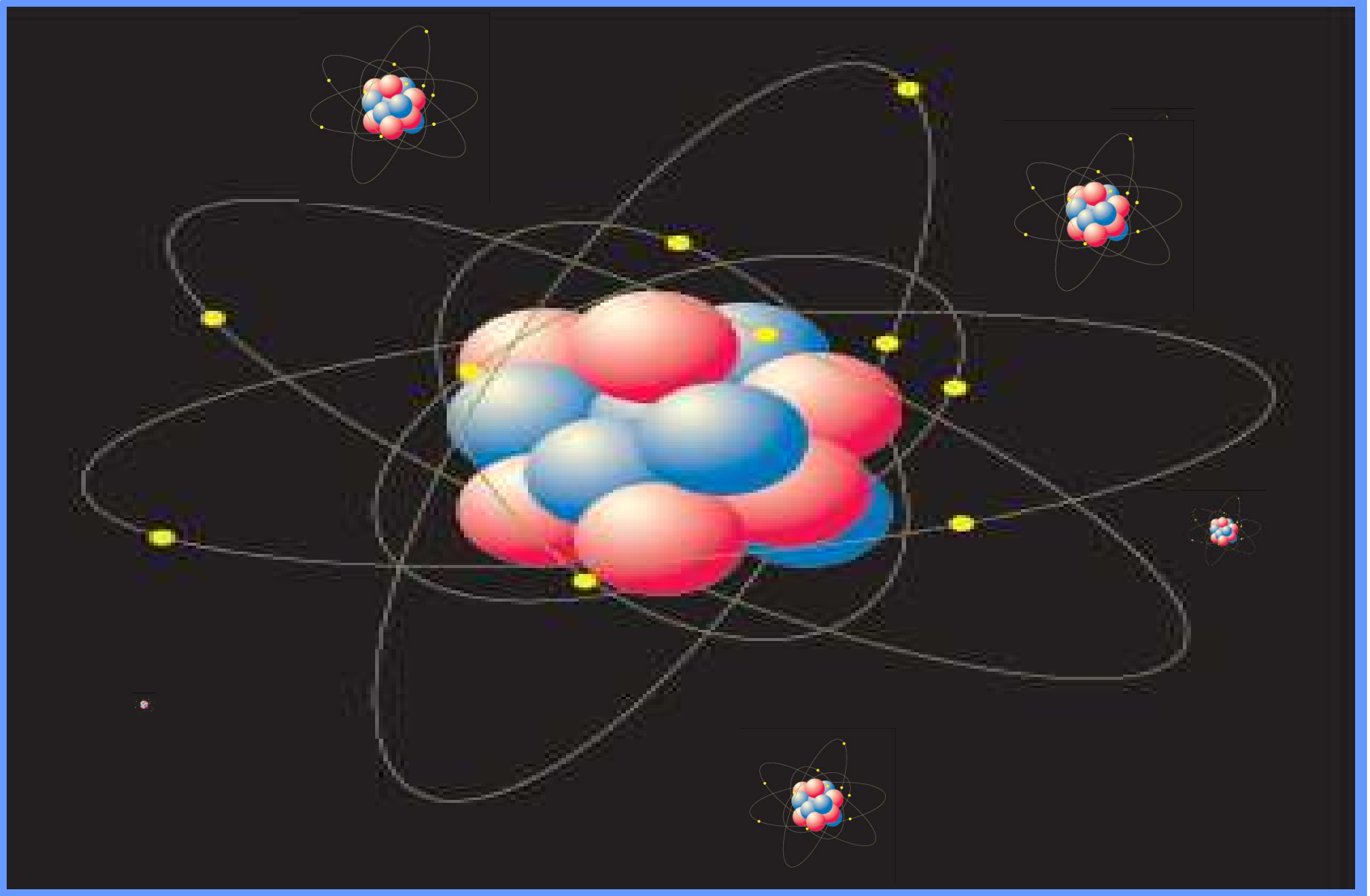
"Electron Cloud Model"



Structure of the Atom

SUBATOMIC PARTICLES

- How small is an atom?



- Activity! Bringing things down to size.

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  - Take one sheet of paper 8 by 11.

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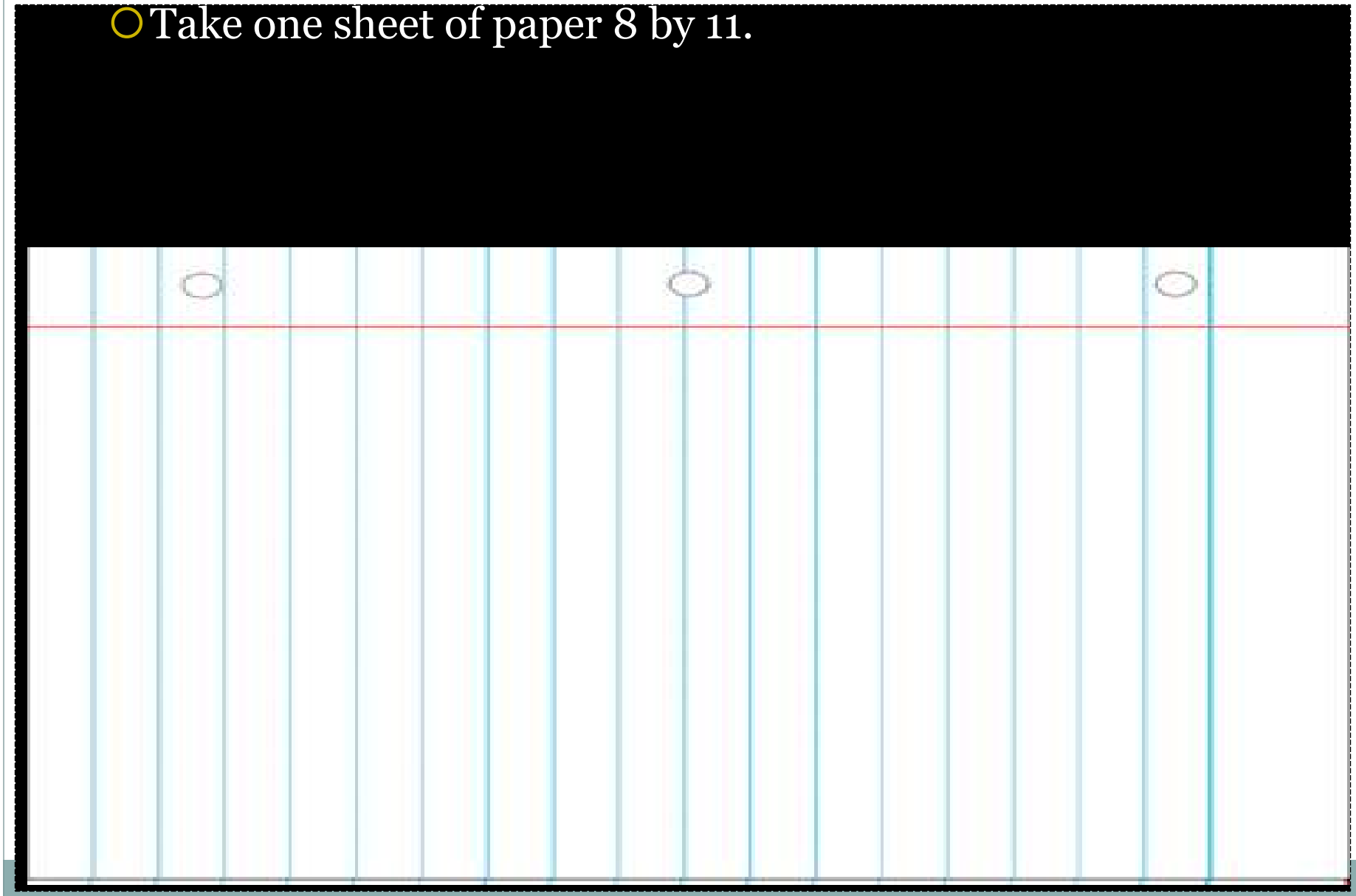
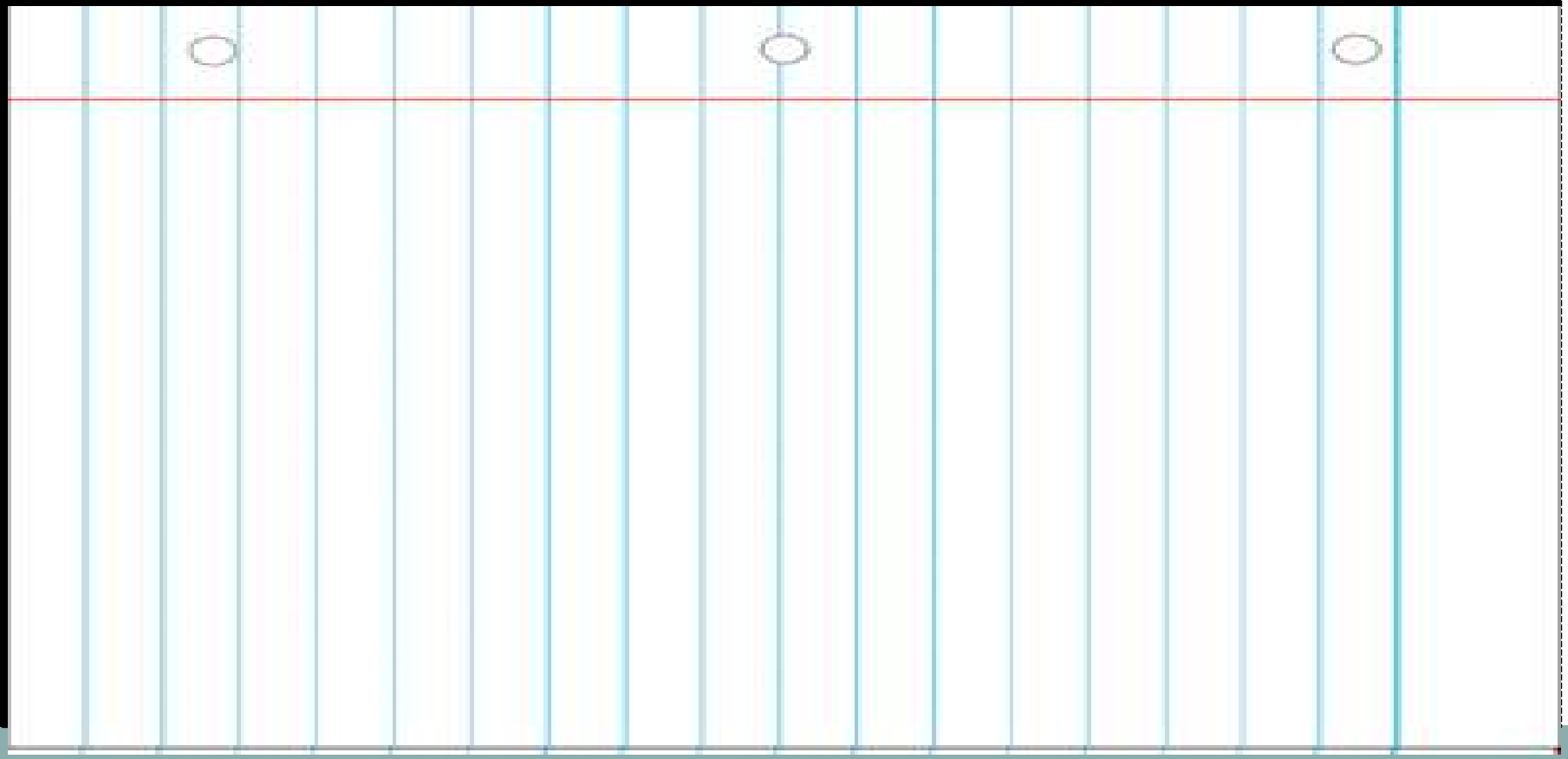


- Activity! Bringing things down to size.
  - Take one sheet of paper 8 by 11.
  - Cut it in half as precisely as possible.



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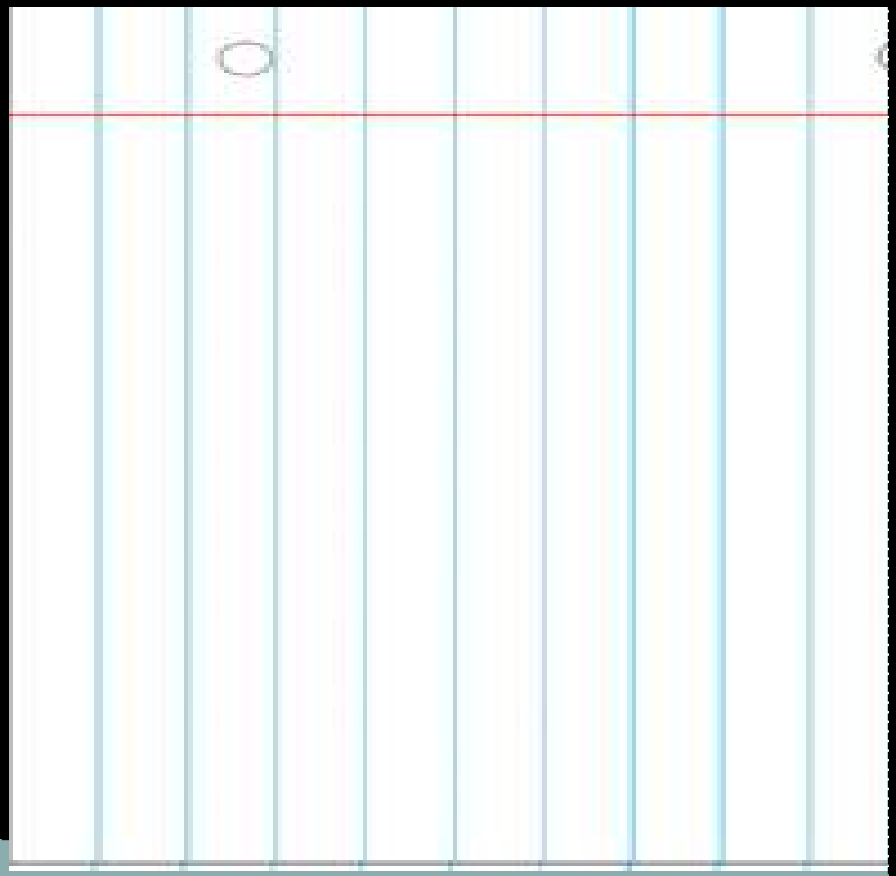
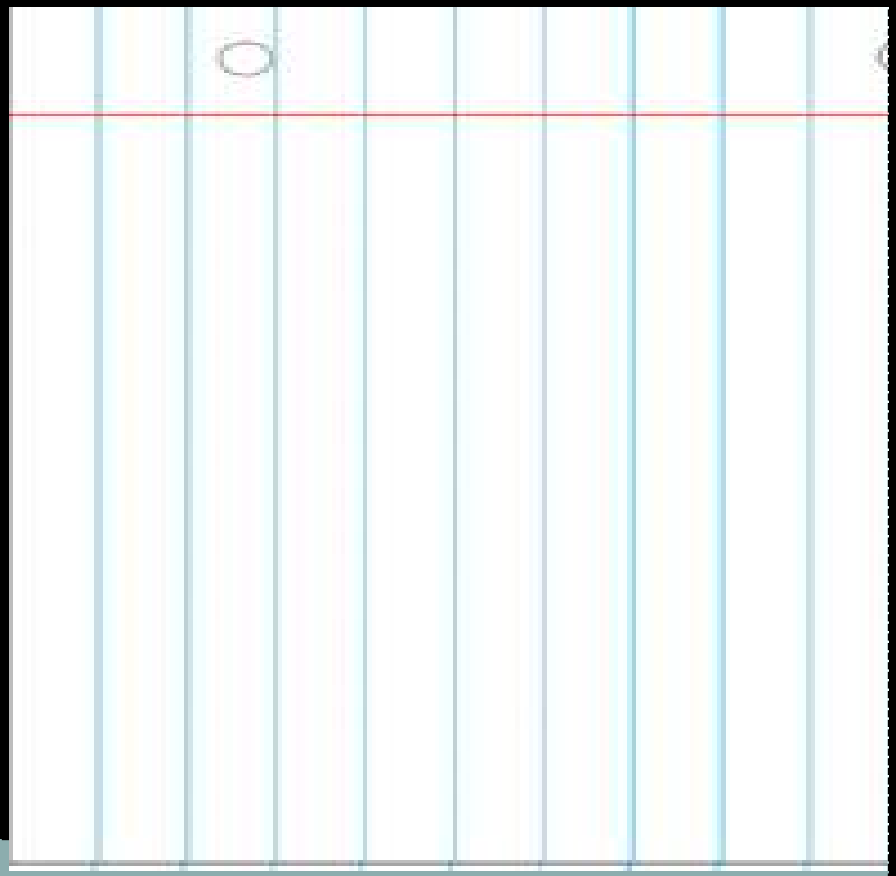


- Activity! Bringing things down to size.
  - Take one sheet of paper 8 by 11.
  - Cut it in half as precisely as possible.
  - Cut in half again and again. Keep track.



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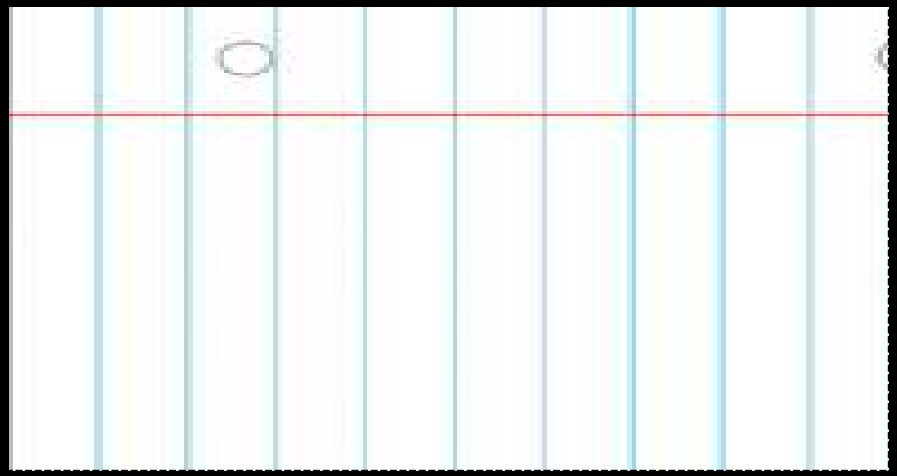

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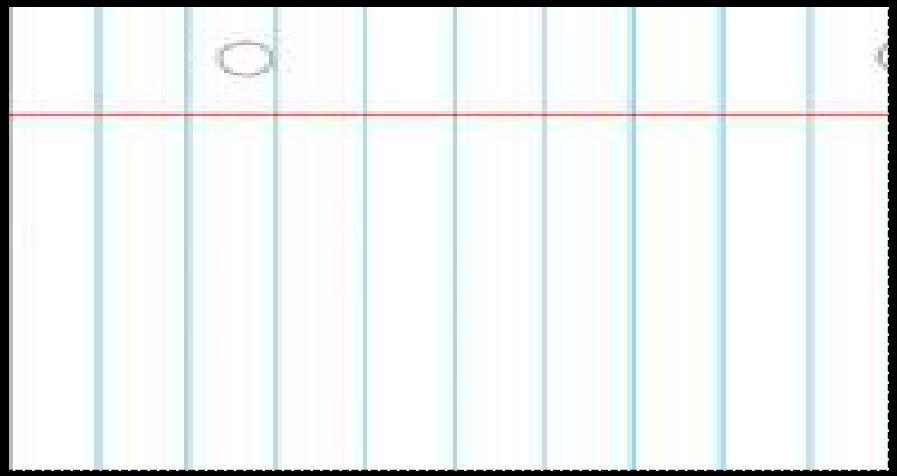

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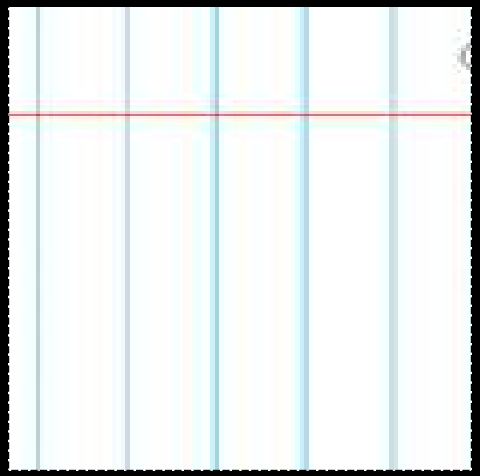

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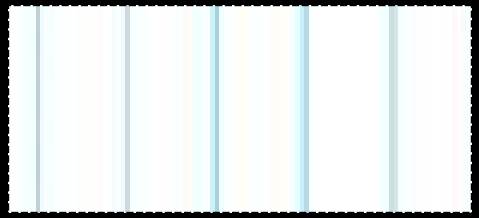

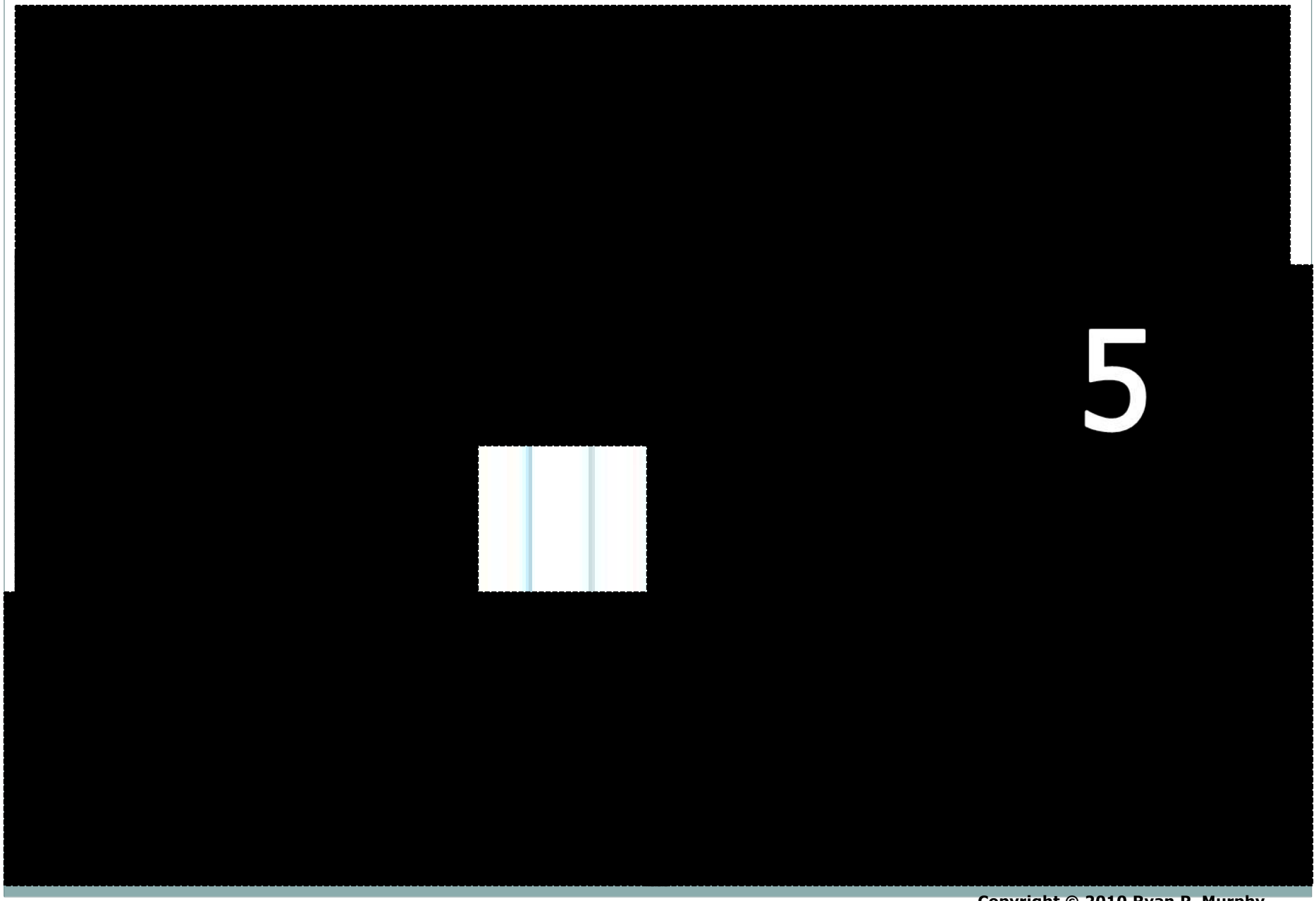

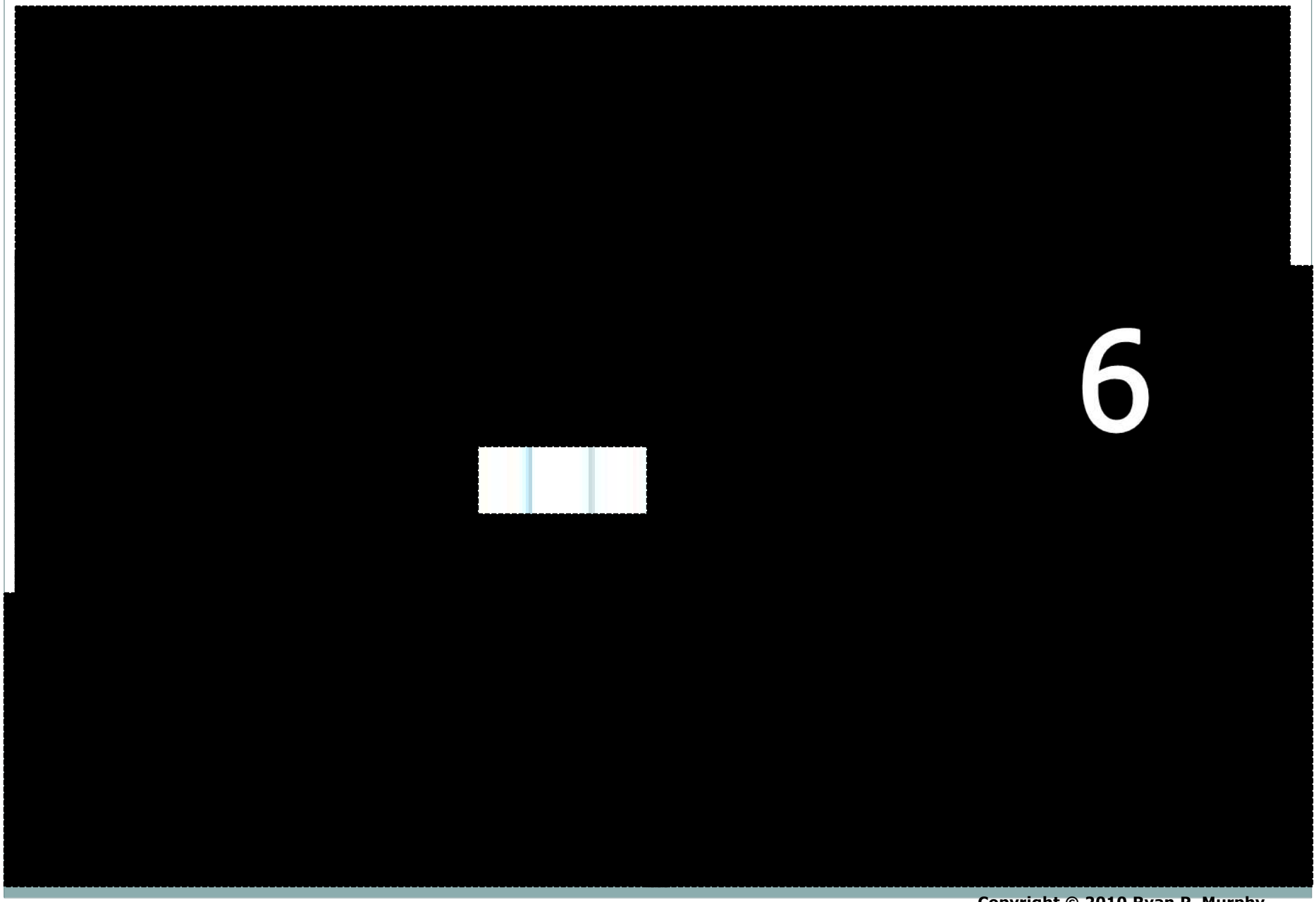

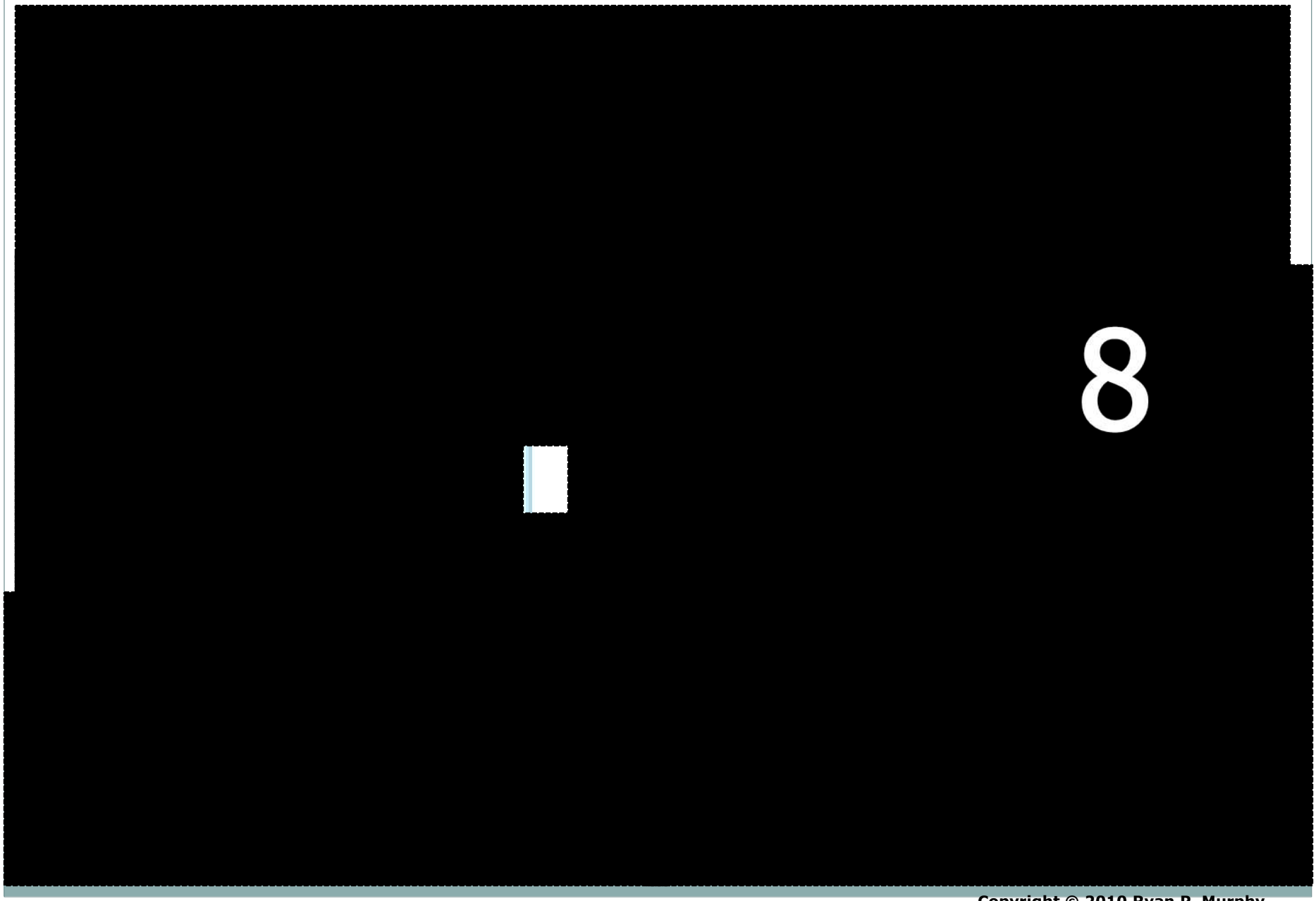

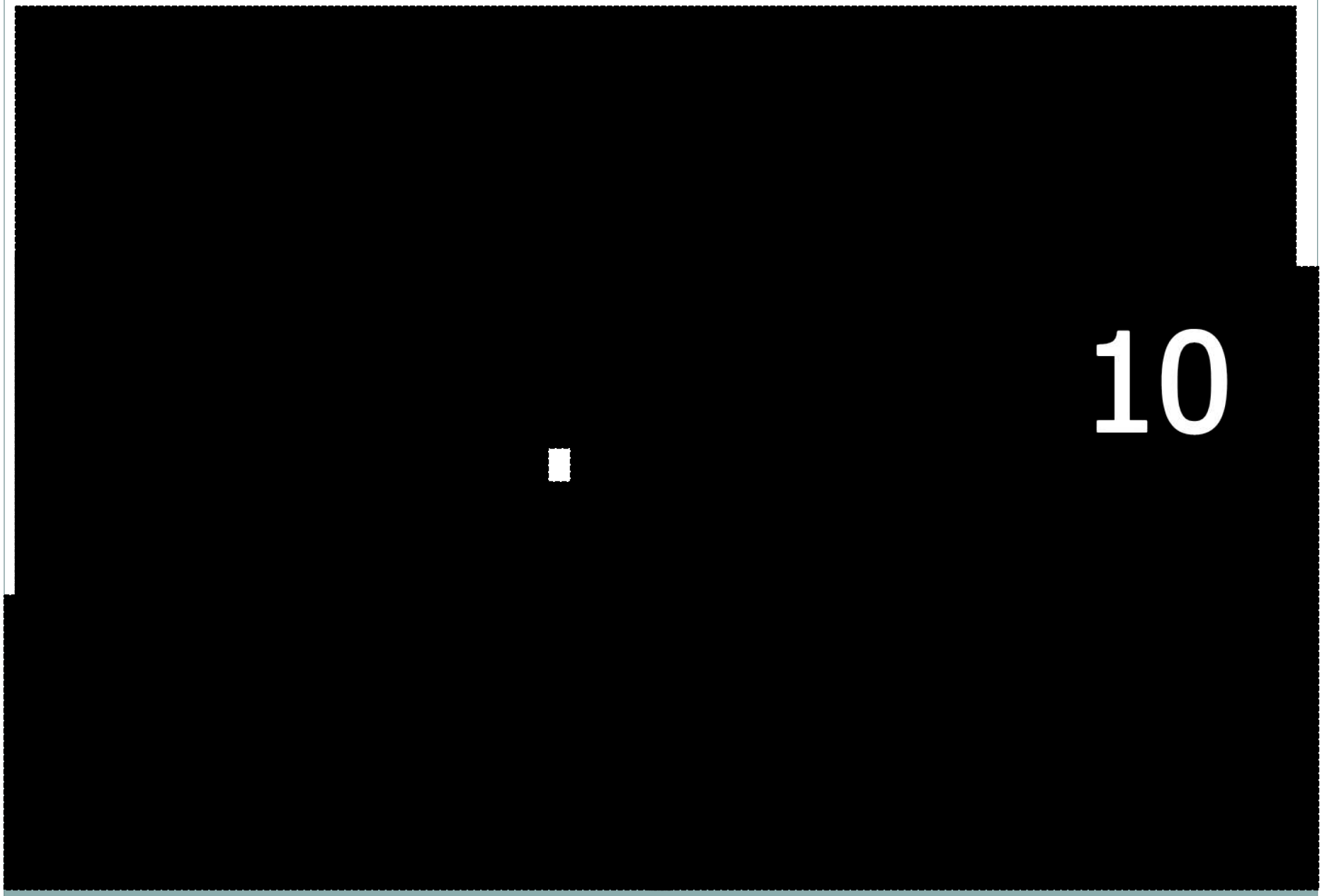

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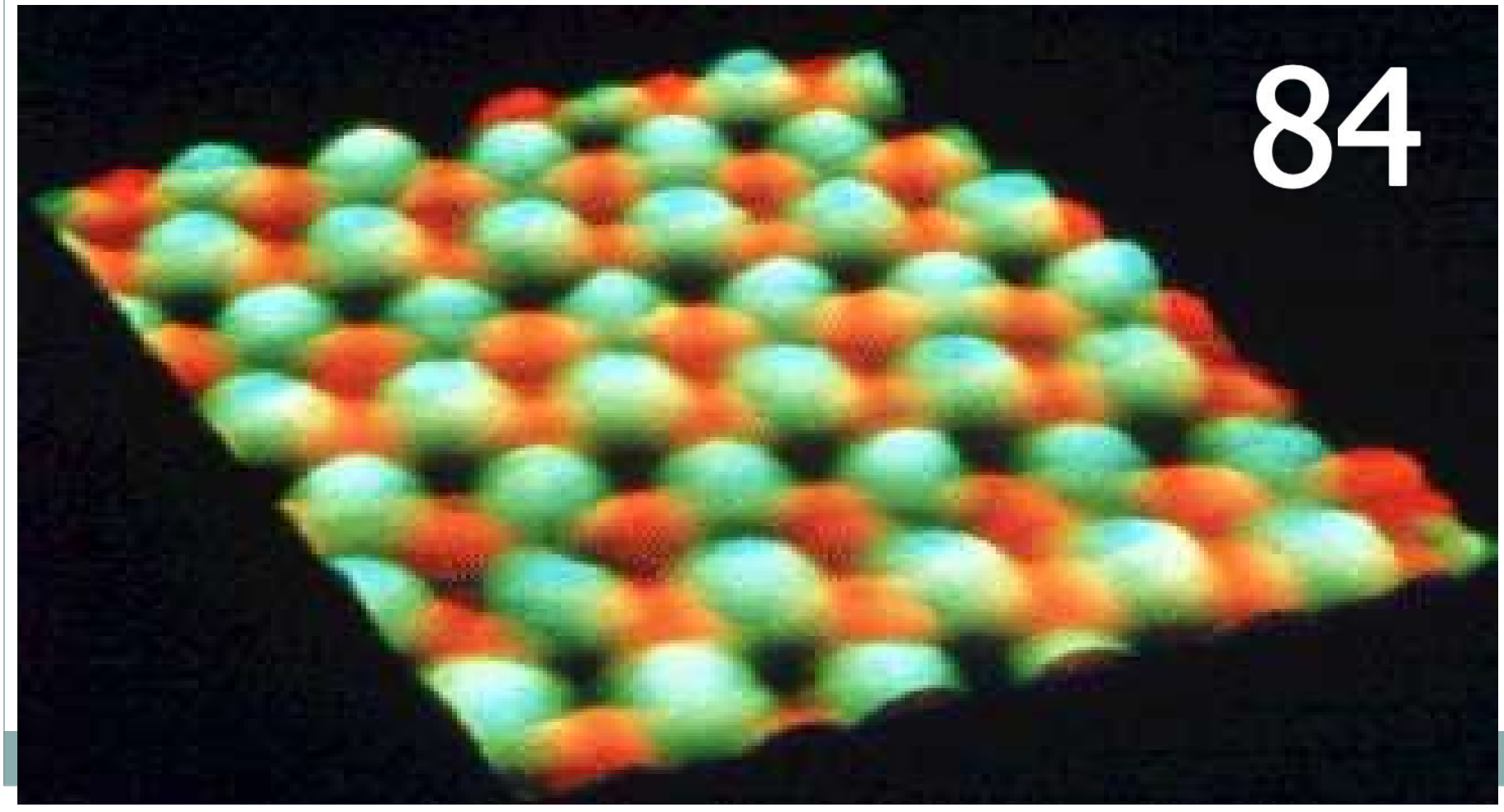
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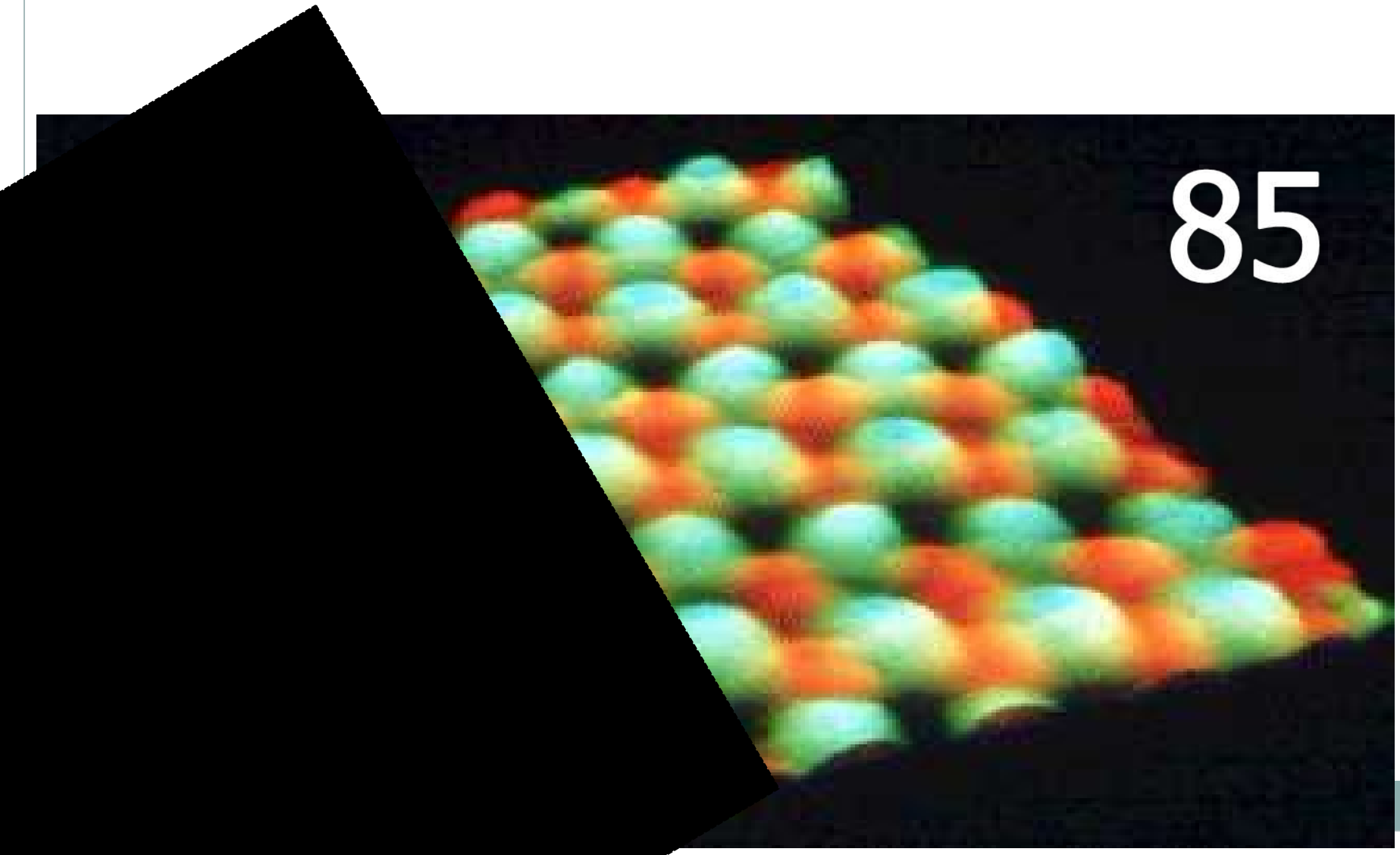
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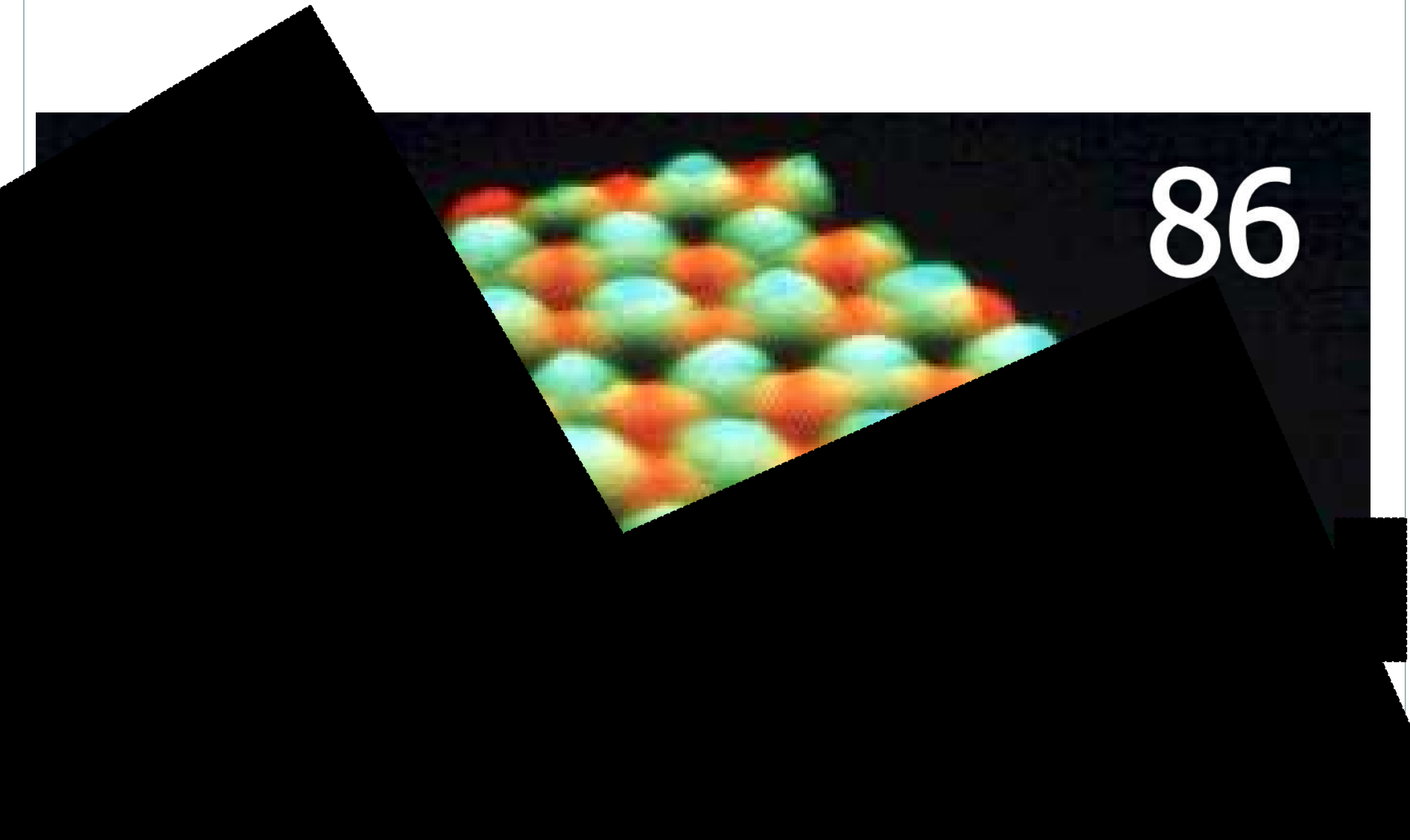
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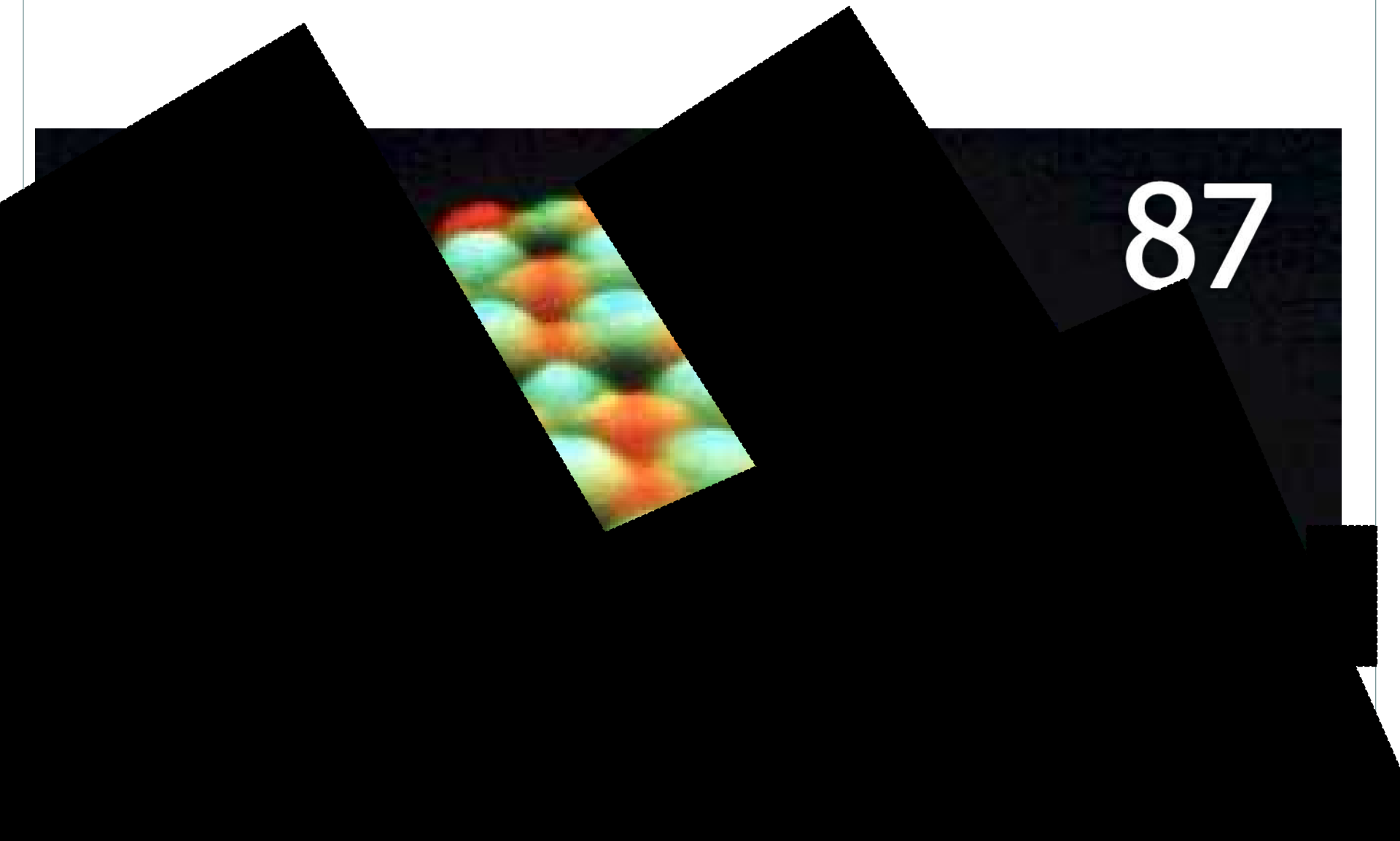
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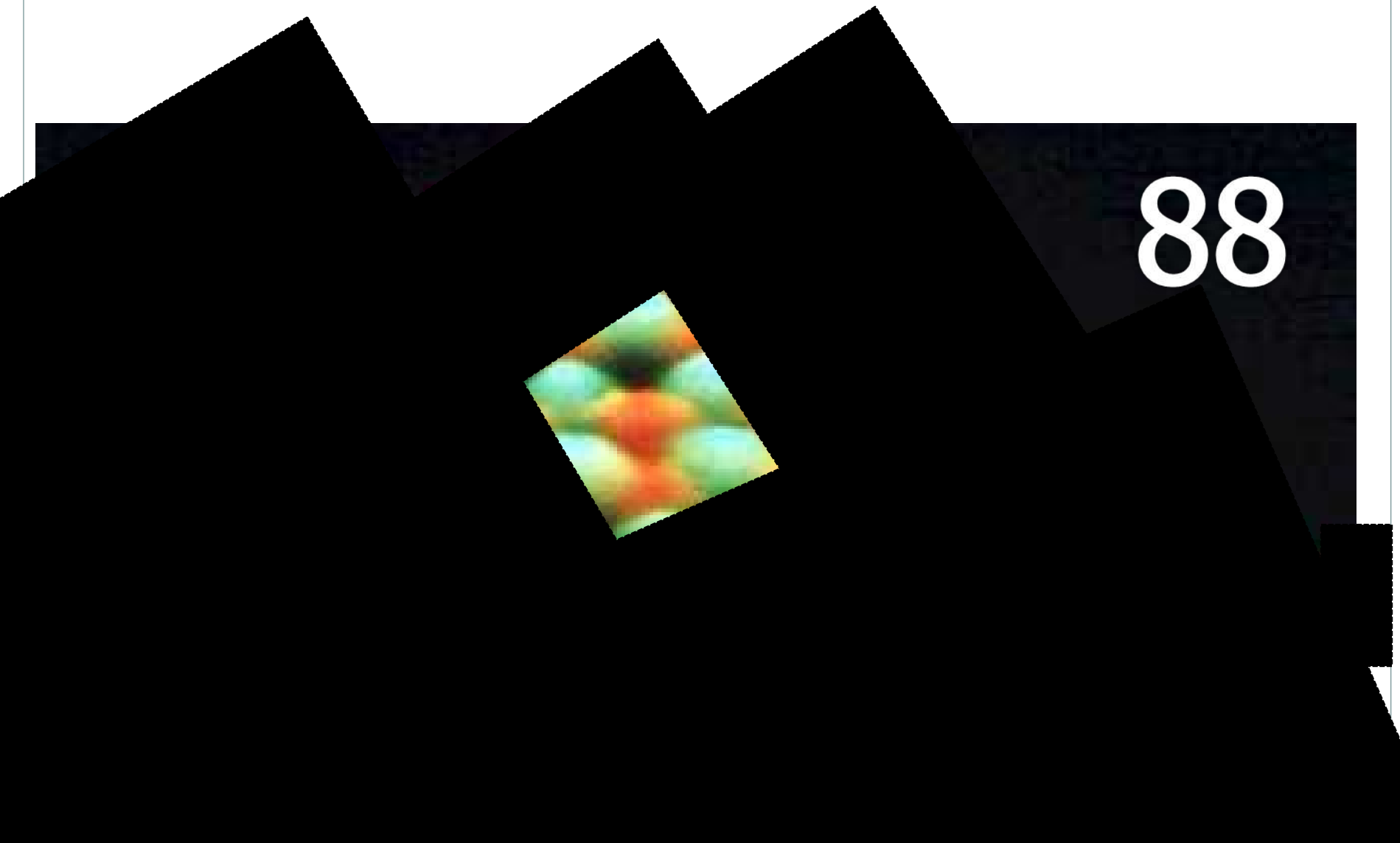
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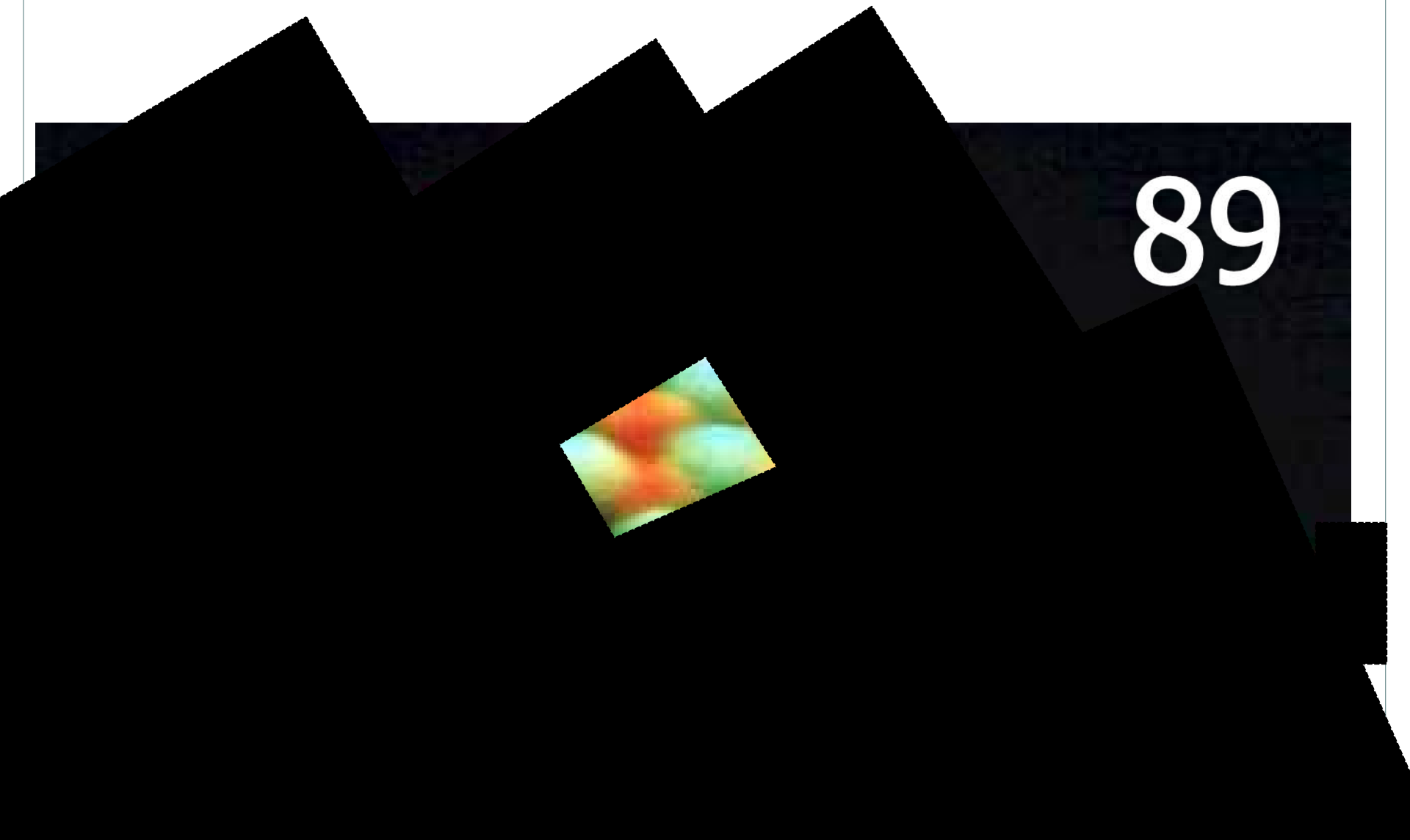
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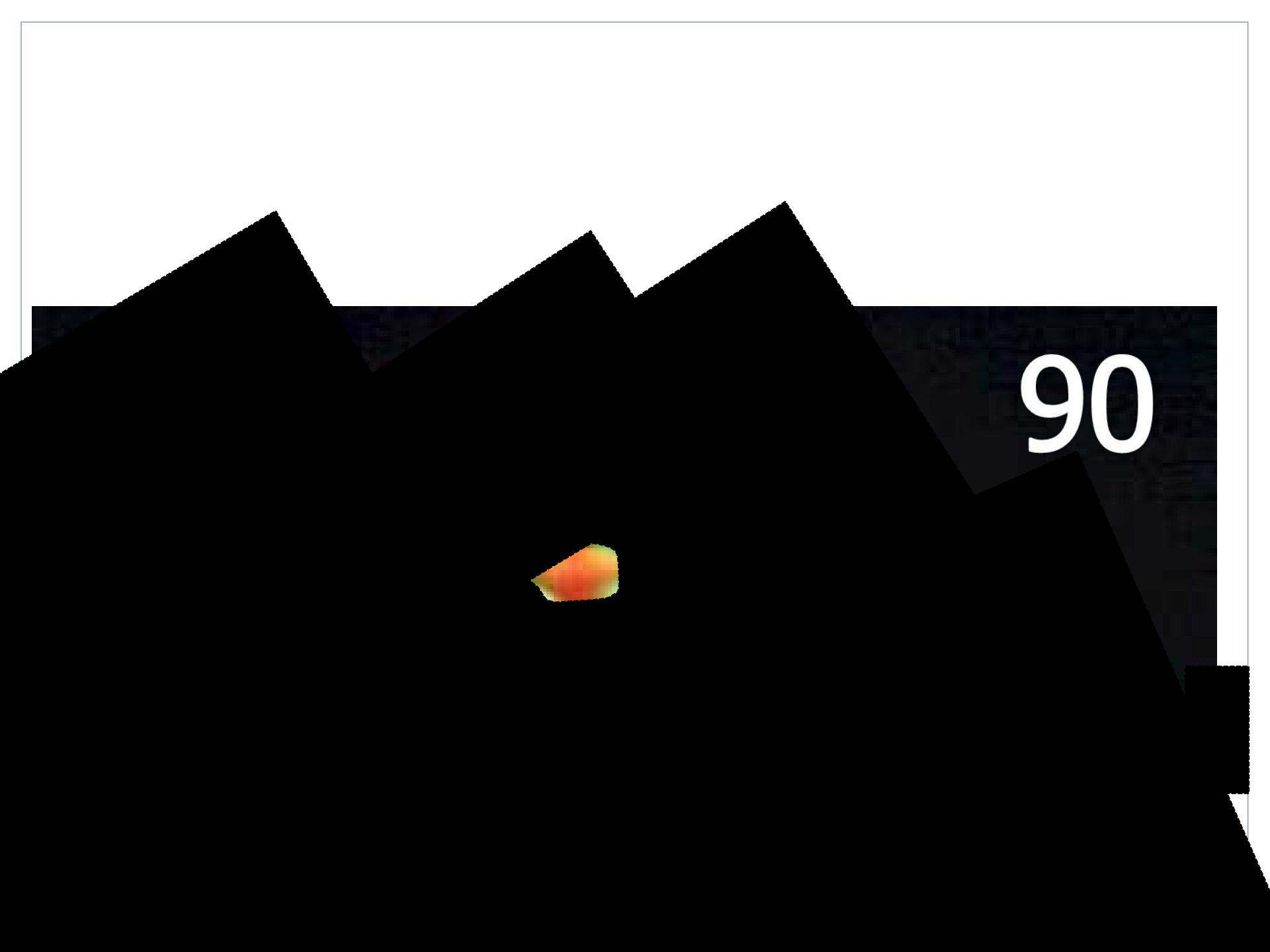
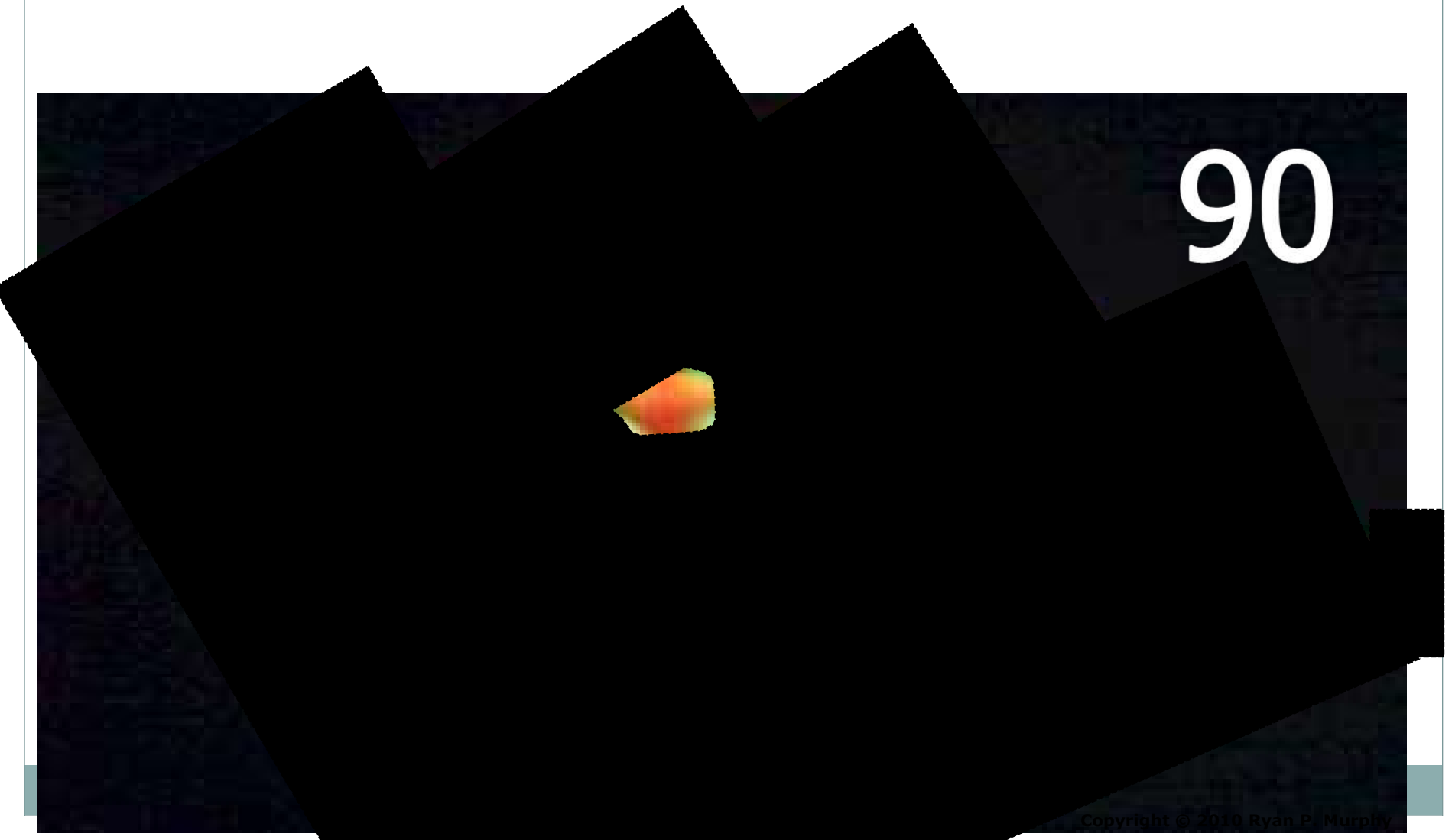
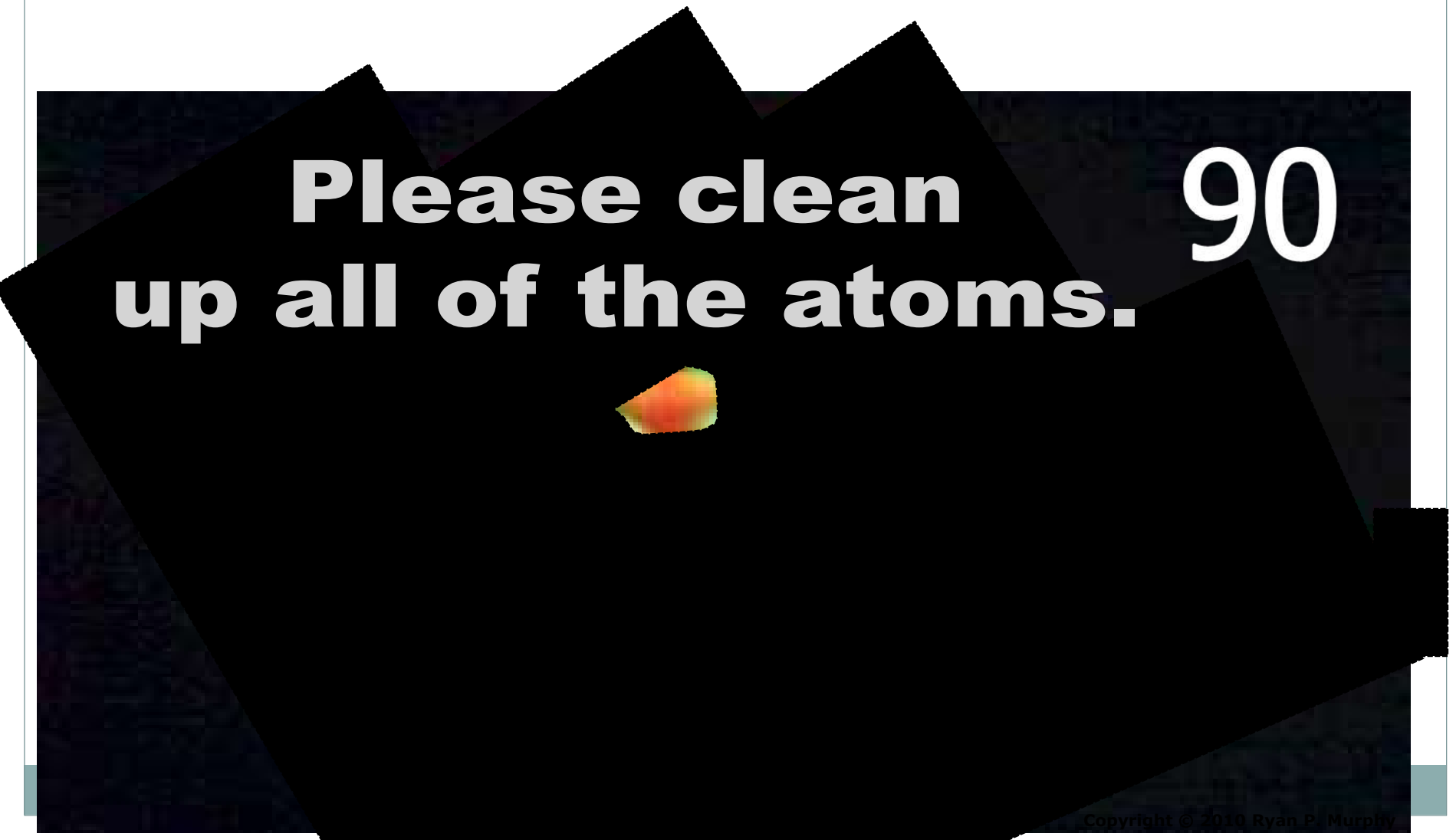

90

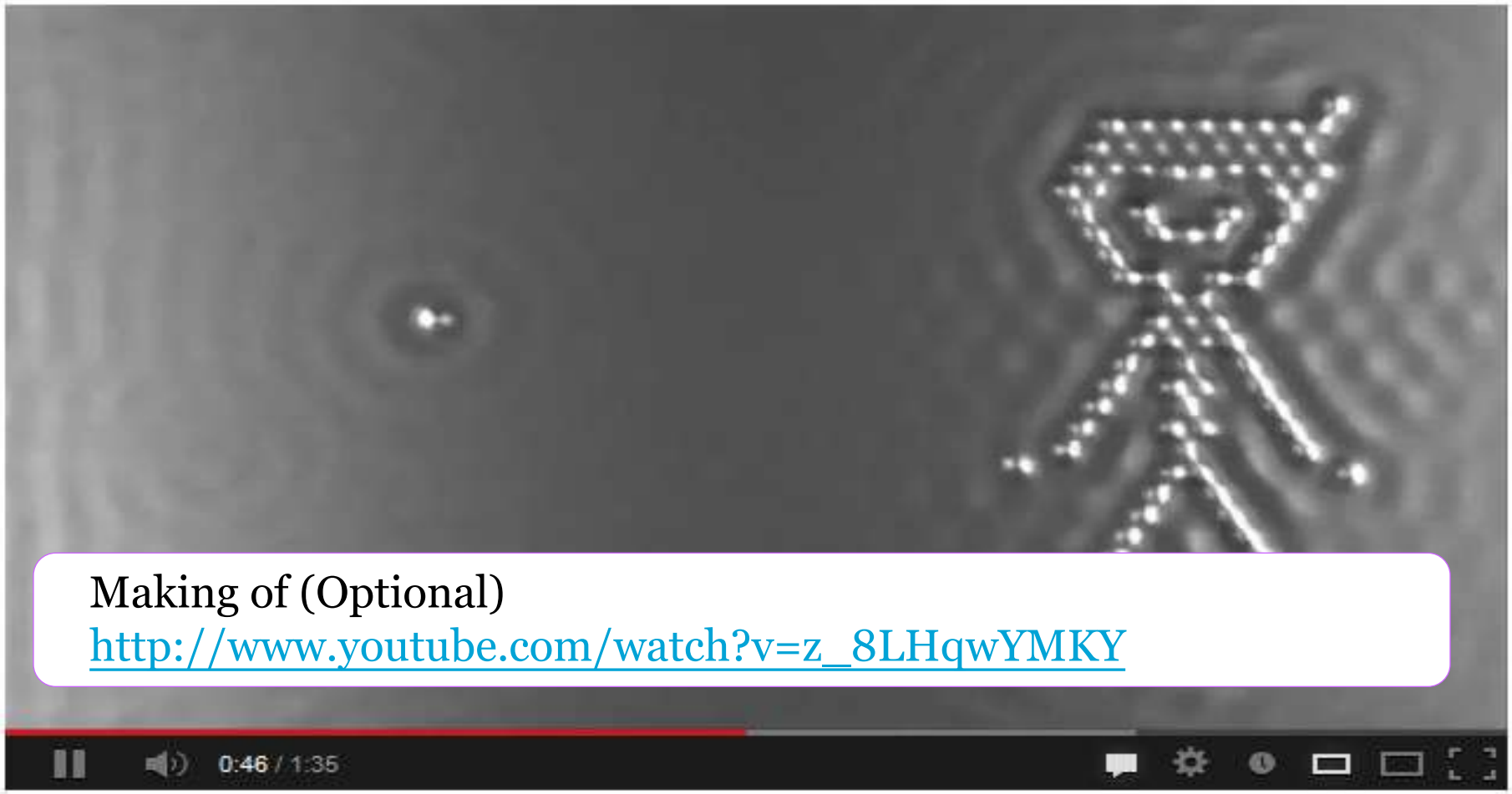
- Answer: If you were to cut the paper in half about 90 times, you would be around the size of the atom. The atom is incredibly small.



- Answer: If you were to cut the paper in half about 90 times, you would be around the size of the atom.



- Video Link! A Boy and His Atom
  - Smallest movie ever made from IBM.
  - http://www.youtube.com/watch?v=oSCX78-8-q0



Making of (Optional)
http://www.youtube.com/watch?v=z_8LHqwYMKY

Sizing Up Atoms

- ATOMS ARE TINY!!!!!!
- A pure copper coin the size of a penny contains 2.4×10^{22} copper atoms. There are only about 6×10^{9} people on Earth!!!
- Individual atoms are observable with instruments such as scanning tunneling microscopes.

Subatomic Particles

- Atoms are now know to be broken down into smaller, more fundamental particles called subatomic particles.
- There are 3 kinds of subatomic Particles.
  - Electrons
  - Protons
  - Neutrons

Mass of Subatomic Particles

- Protons and neutrons have approximately the same mass (in the range of 10^{-24} g).
  - Neutrons are slightly heavier.
  - Mass is expressed in amu
    - Atomic mass unit (amu) – 1/12 the mass of a carbon-12 atom

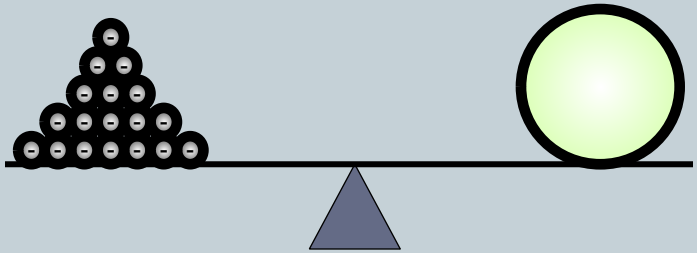
Mass of Subatomic Particles

- The mass of the electron is tiny as compared to that of the proton and neutron.
  - Therefore, the electron's mass is considered to be about 0 amu when calculating the mass of an atom.

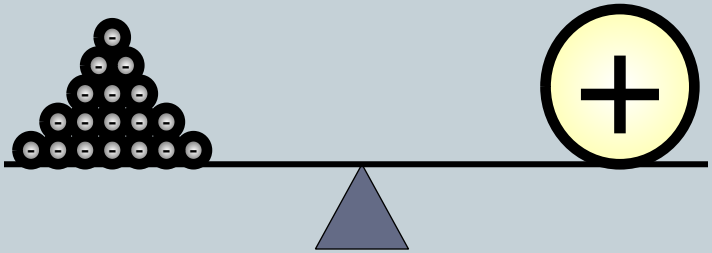
Weight Comparison

(protons, neutrons, electrons)

Neutron = $1.6749286 \times 10^{-27}$ kg
Proton = $1.6726231 \times 10^{-27}$ kg
Electron = $9.1093897 \times 10^{-31}$ kg



1839 electrons = 1 neutron



1836 electrons = 1 proton

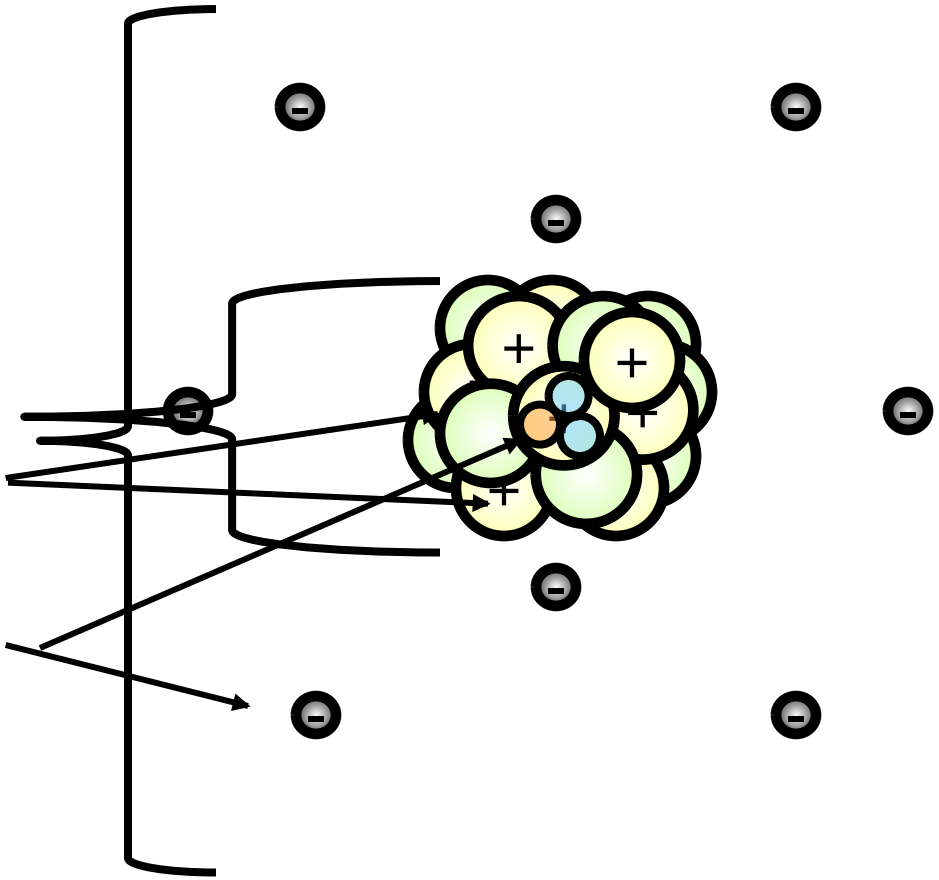
How do you think the mass of a neutron compares to that of a proton?

1 neutron ≈ 1 proton

Size Comparison

(protons, neutrons, electrons, & quarks)

	Size in atoms	Size in meters (m)
Atom	1	10^{-10}
Nucleus	$\frac{1}{10,000}$	10^{-14}
Proton or Neutron	$\frac{1}{100,000}$	10^{-15}
Electron or Quark	$\frac{1}{100,000,000}$	10^{-18} (at largest)

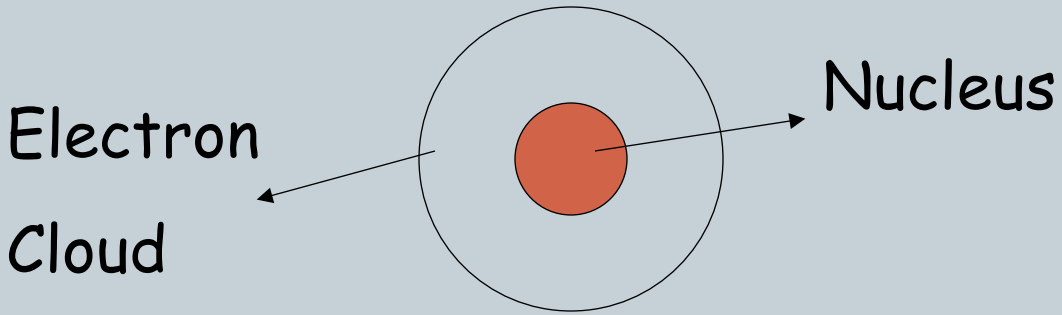


Subatomic Particles

Subatomic Particle	Charge	Mass, amu	Location in atom
Electron (e-)	-1	0 amu	Outside of nucleus
Proton (p)	+1	~1 amu	Nucleus
Neutron (n)	0	~1 amu	Nucleus

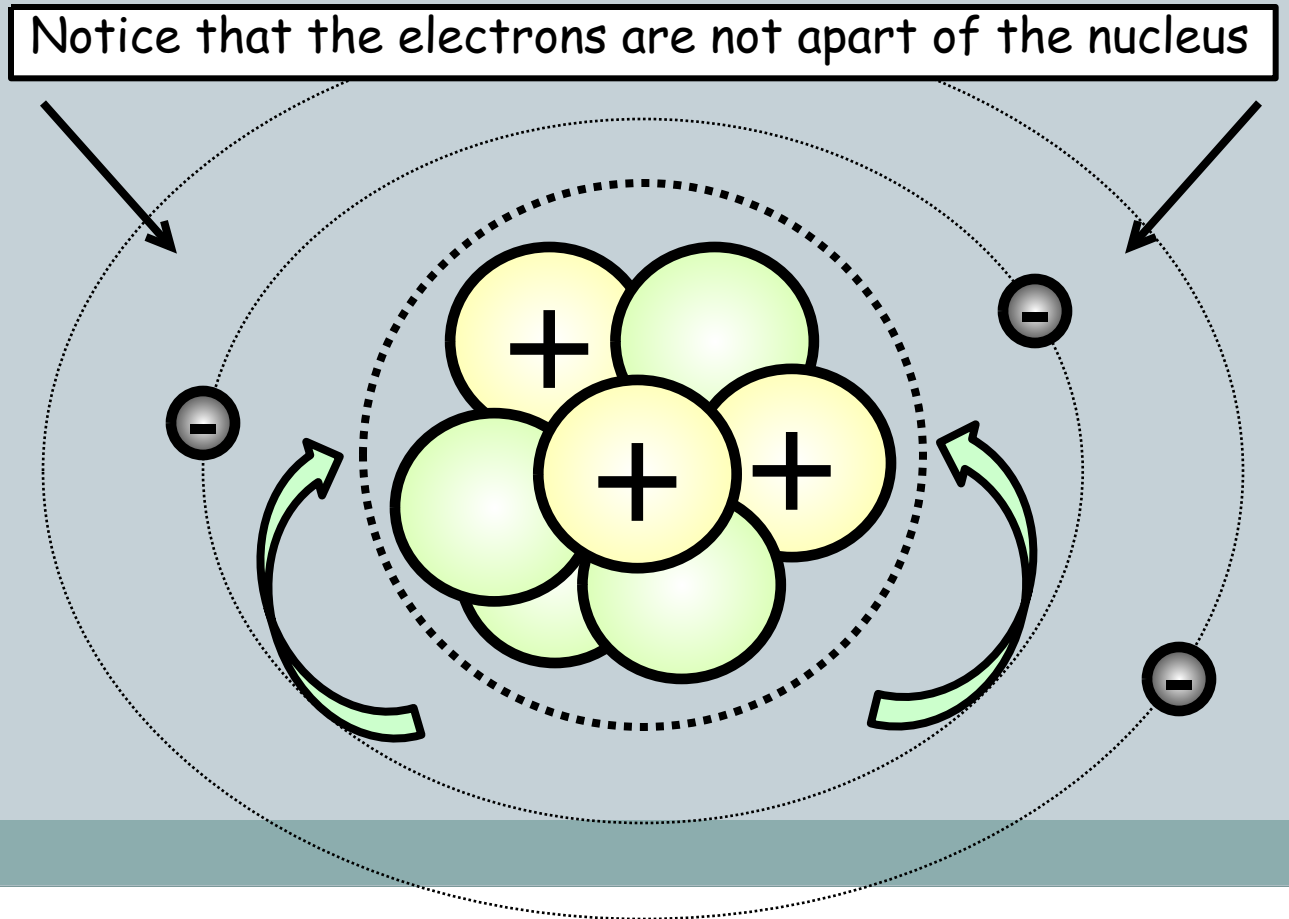
Atomic Structure

- Atoms are composed of 2 regions:
  - Nucleus: the center of the atom that contains the mass of the atom
  - Electron cloud: region that surrounds the nucleus that contains most of the space in the atom



The Atom's "Center"

- Protons and neutrons are grouped together to form the "center" or **nucleus** of an atom.



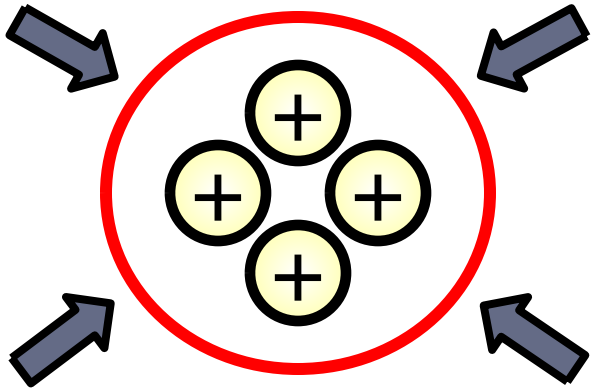
What's in the Nucleus?

- The nucleus contains 2 of the 3 subatomic particles:
  - Protons: positively charged subatomic particles
  - Neutrons: neutrally charged subatomic particles

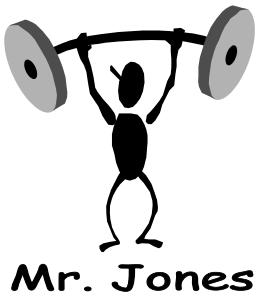
Strong Force

- The force that holds the atomic nucleus together
- The force that counteracts the electromagnetic force

Notice how the electromagnetic force causes the protons to repel each other but, the strong force holds them together.



If you need help remembering strong force, just think of…



Would an atom have a nucleus if the strong force did not exist?

What's in the Electron Cloud?

- The 3rd subatomic particle resides outside of the nucleus in the electron cloud
  - Electron: the subatomic particle with a **negative** charge and relatively no mass

How do these particles interact?

- Protons and neutrons live compacted in the tiny positively charged nucleus accounting for most of the mass of the atom
- The negatively charged electrons are small and have a relatively small mass but occupy a large volume of space outside the nucleus

How do the subatomic particles balance each other?

- In an atom:
  - The protons = the electrons
    - If 20 protons are present in an atom then 20 electrons are there to balance the overall charge of the atom—**atoms are neutral**
  - The neutrons have no charge; therefore they do not have to equal the number of protons or electrons

How do we know the number of subatomic particles in an atom?

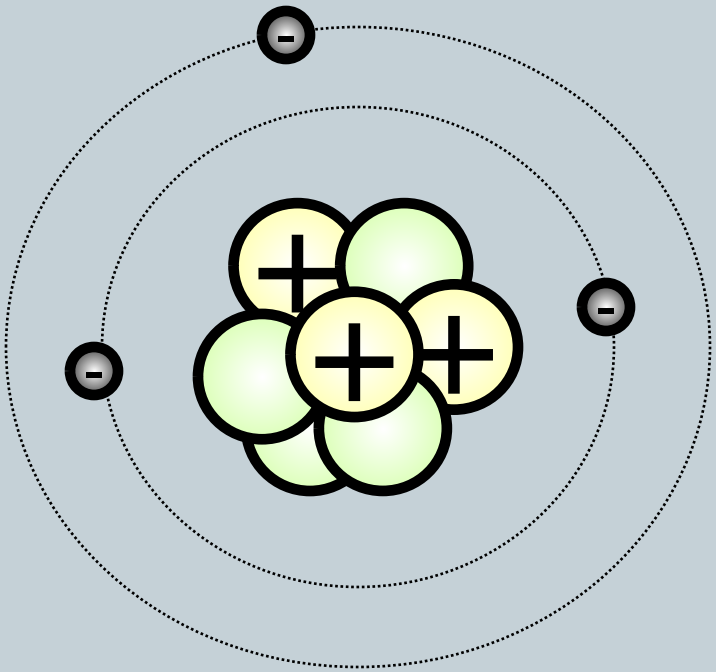
- Atomic number: this number indicates the number of protons in an atom
  - Ex: Hydrogen's atomic number is 1
    - So hydrogen has 1 proton
  - Ex: Carbon's atomic number is 6
    - So carbon has 6 protons

**The number of protons identifies the atom.

Ex. 2 protons = He, 29 protons = Cu

Atomic Number

- The number of protons in the nucleus of an atom



What would be the atomic number of this atom?

How do we know the number of subatomic particles in an atom?

- Mass number: the number of protons and neutrons in the nucleus
  - Ex: hydrogen can have a mass of 3.

    Since it has 1 proton it must have 2 neutrons
  - # of neutrons = mass # - atomic #

Mass Number

- The total number of protons and neutrons in an atom's nucleus
- Expressed in **A**tomic **M**ass **U**nits (amu)
  - Each proton or neutron has a mass of 1 amu

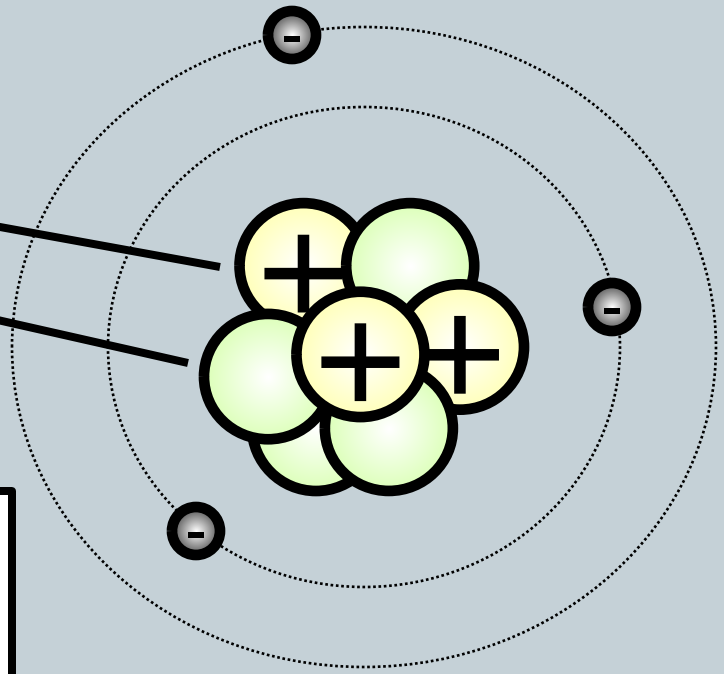
What would be the mass number of this atom?

→ 3

→ 4

3 protons + 4 neutrons = a mass number of 7 amu

Why did we not account for the electrons when calculating the mass number?



Determining the number of protons and neutrons

- Li has a mass number of 7 and an atomic number of 3
  - Protons = 3 (same as atomic #)
  - Neutrons= 7-3 = 4 (mass # - atomic #)
- Ne has a mass number of 20 and an atomic number of 10
  - Protons = 10
  - Neutrons = 20 - 10= 10

What about the electrons?

- The electrons are equal to the number of protons
  - So E^- = P = atomic #
- Ex: He has a mass # of 4 and an atomic # of 2
  - $P^+ = 2$
  - $N^o = 2$
  - $E^- = 2$

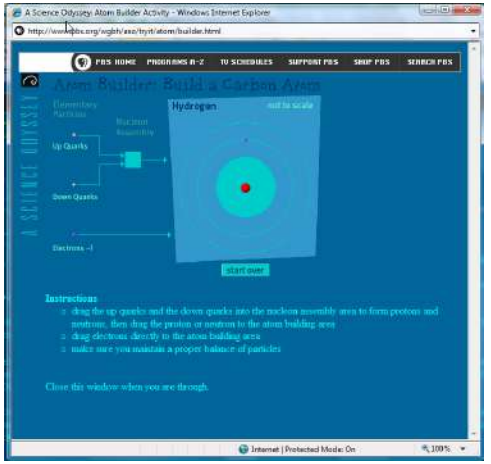
Building Atoms

Using the whiteboard and the proton, neutron, and electron pieces, build the following atoms, and determine their atomic and mass numbers.

Atoms	Protons	Neutrons	Electrons
Carbon	6	6	6
Beryllium	4	5	4
Oxygen	8	8	8
Lithium	3	4	3
Sodium	11	12	11

Atom Builder

- Using the interactive website link below, practice building atoms.



- http://www.pbs.org/wgbh/aso/tryit/atom/

- Using the classzone.com link below, click on the "Build an Atom" simulation and practice building atoms.

http://www.classzone.com/books/ml_sci_physical/page_build.cfm?id=resour_ch1&u=2##

Crash Course

- To Review
- https://www.youtube.com/watch?feature=player_detailpage&v=FSyAehMdpyI