What is an atom?

Why are we doing this?

Atoms are the fundamental building blocks of all substances. To begin to understand the properties of atoms and how they combine to form molecules, you must be familiar with their composition and structure. However, atoms are extremely small. So small, in fact, that you cannot see an individual atom with your naked eye. In order to help visualize the structure and composition of atoms, we will be using a variety of models to make the unseen, seen.

Your Learning Outcomes

You will be able to:

1. Describe and represent the composition and structure of atoms, isotopes, and ions.
2. Use atomic symbols, names, and models to identify the number of particles composing an atom, isotope, or ion.

The Plan

1. Assign roles*.
    a. ***Manager*** – This person will keep the team on task and provide direction to the group. This person is responsible for uploading the group's work to Gradescope. Make sure you make a note of everyone in the group. You must add everyone's name when submitting your answers to Gradescope.
    b. ***Spokesperson*** – This person will represent the group be responsible for speaking for the group to the rest of the class.
    c. ***Recorder*** – This person will be responsible for recording the team's answers to the Critical Thinking Questions in an organized and coherent manner.
    d. ***Analyst*** – This person will be responsible for critical analysis of the team's work (i.e., the Devil's Advocate). This person should make sure everyone understands what is happening before the group moves forward.
2. Complete the Critical Thinking Questions as a group.
3. Submit your team's work via Gradescope. Groups may choose to work in a Word document or write out their answers on a separate sheet of paper. All work must be upload to Gradescope as a PDF file.

**Students may choose to complete this activity independently if they are unable to attend discussion due to illness or injury; in which case, the student must perform all roles and complete all aspect of the activity. To receive full credit, documentation as to the need for the absence from discussion must be included with the submission and your TA must be notified of the absence.*

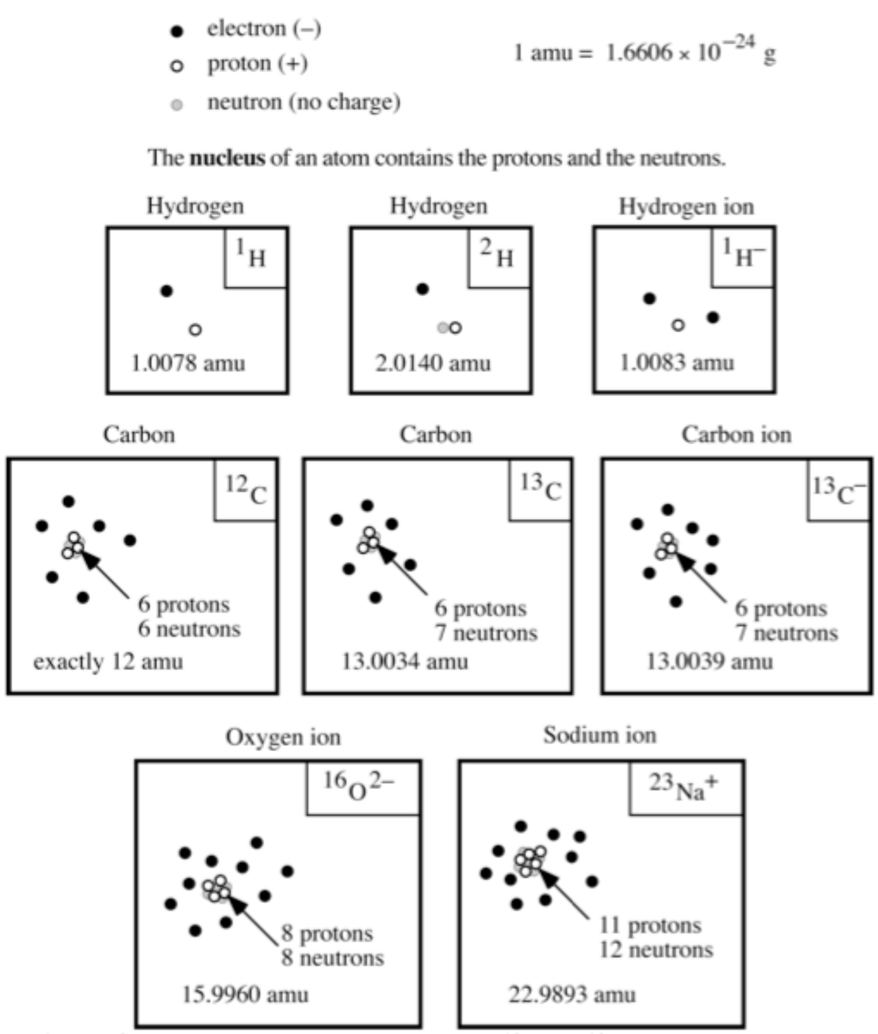
Information:

An important practice of both science and engineering is to use and construct models as helpful tools for representing ideas and explanations. Models include diagrams, physical replicas, mathematical representations, analogies, and computer simulations. Although models do not correspond exactly to the real world, they bring certain features into focus while obscuring others. All models contain approximations and assumptions that limit the range of validity and predictive power, so it is important for students to recognize their limitations.

In science, models are used to represent a system (or parts of a system) under study, to aid in the development of questions and explanations, to generate data that can be used to make predictions, and to communicate ideas to others. Students can be expected to evaluate and refine models through an iterative cycle of comparing their predictions with the real world and then adjusting them to gain insights into the phenomenon being modeled. As such, models are based upon evidence. When new evidence is uncovered that the models can't explain, models are modified.

In engineering, models may be used to analyze a system to see where or under what conditions flaws might develop, or to test possible solutions to a problem. Models can also be used to visualize and refine a design, to communicate a design's features to others, and as prototypes for testing design performance

Model 1: Schematic Diagrams of Various Atoms



^{1}H and ^{2}H are **isotopes** of hydrogen. ^{12}C and ^{13}C are **isotopes** of carbon.

Critical Thinking Questions

1. How many protons are found in ^{12}C? ^{13}C? $^{13}C^{-}$?
   6, 6, 6

2. How many neutrons are found in ^{12}C? ^{13}C? $^{13}C^{-}$?
   6, 7, 7

3. How many electrons are found in ^{12}C? ^{13}C? $^{13}C^{-}$?
   6, 6, 7

4. Based on your answers to Critical Thinking Questions (CTQs) 1-3, what do all carbon atoms (and ions) have in common?
   All carbon atoms and ions have six protons in the nucleus.

5. Based on the model, what do all hydrogen atoms (and ions) have in common?
   All hydrogen atoms and ions have one proton in the nucleus.

6. Based on your answers to CTQs 4 and 5, what is the significance of the atomic number, Z, above each atomic symbol in the periodic table?
   Z is the number of protons in the nucleus of that atom.

7. Based on your answer to CTQ 6, what do all nickel (Ni) atoms have in common?
   Twenty-eight protons in the nucleus.

8. In terms of the numbers of protons, neutrons and electrons:
    a. Why does the notation $^{13}C^{-}$ have a negative sign in the upper right-hand corner?
    Because there is a net charge on the species: there are six protons and 7 electrons.

    b. What feature distinguishes a neutral atom from an ion?
    A neutral atom has equal numbers of protons and electrons; in an ion, the number of protons and electrons are not equal.

    c. Provide an expression for calculating the charge on an ion.
    The charge on an ion = # of protons – # of electrons.

9. Determine the number of protons, neutrons, and electrons in one $^{1}H^{+}$ ion. Explain how you found your answer.

    Because every H atom must have one proton, the number of protons is 1. All of the ^{1}H species in the model have no neutrons, so by analogy there will be 0 neutrons in this ion. Also, the number of electrons is zero because the charge is 1+ and there has to be one proton, which has a charge of +1.

10. What structural feature is different in isotopes of a particular element?
    Different isotopes on a particular element have a different number of neutrons in the nucleus (but the same number of protons).

11. How is the mass number, A, (left-hand superscript next to the atomic symbol as shown in the model) determined (from the structure of the atom)?
    The mass number, A, is the sum of the number of protons and the number of neutrons in the nucleus.

12. Show that the mass number and charge given for $^{16}O^{2-}$ and $^{23}Na^{+}$ are correct in the model.
    The O atom has 8 protons and 8 neutrons in its nucleus; hence, the mass number is 16. The O atom has 8 protons and 10 electrons; hence the charge on the ion is 2–. The Na atom has 11 protons and 12 neutrons; hence, the mass number is 23. The Na atom has 11 protons and 10 electrons; hence the charge on the ion is 1+.

13. According to the model, the mass of carbon-12 is 12 amu. What percentage of this mass is located in the nucleus? Explain the significance of your answer.
    ((12 amu – 6(0.0005 amu))/12 amu)*100 = 99.975%
    Most of the mass of the atom (almost 100%) is found in the nucleus because the mass of the electrons (not found in the nucleus) is very small.

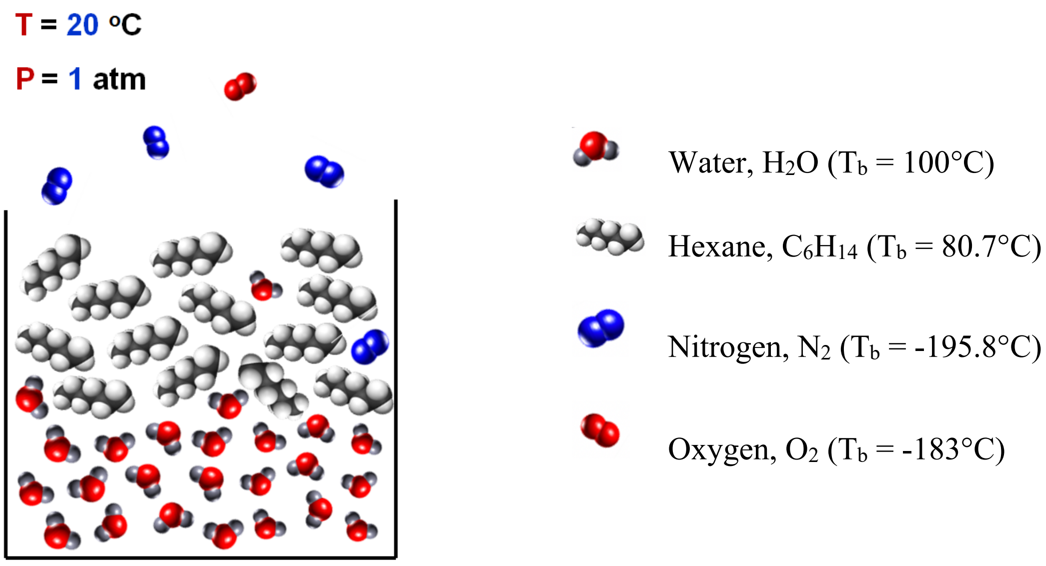
14. The radius of a chlorine nucleus is 4.0 fm, and the radius of a chlorine atom is 100 pm. 1 femtometer (fm) is equal to 1×10^{-15} meters. 1 picometer (pm) is equal to 1×10^{-12} meters. If you were going to create a model of a chlorine atom using a dime to represent the nucleus, which of the following would be the approximate size of your chlorine atom model?
    a. The size of a quarter.
    b. The size of a car.
    c. The size of a football stadium.
    d. The size of the Earth.

    Explain how you made your decision.
    $(100 \times 10^{-12} m / 4 \times 10^{-15} m) = (x/17.9 mm)$
    $x = 4.475 \times 10^{5}$ mm (1m/1000 mm) = 447.5 m ~ football stadium

Information:

In addition to subatomic particles such as protons, neutrons, or electrons, models can be used to represent larger substances such as atoms, ions, or compounds. As such, it is important that particulate level models include a legend or key to identify what each symbol represents.

Model 2: Particulate Model of a Mixture of Elements and Compounds



Critical Thinking Questions

15. An element is composed of a single type of atom. A compound is composed of two or more types of elements. Based on the particulate model shown in Model 2,
    a. How many elements are present? Explain your reasoning.
       2—N_2 and O_2 are both made up of the same type of atoms in each. Therefore, they are diatomic elements.

    b. How many compounds are present? Explain your reasoning.
       2— H_2O and C_6H_{14} are both compounds because they are made up of two different types of atoms each.

16. How many phases are present in Model 2? Explain your reasoning.
    2— Water and hexane are close packed and randomly arranged indicating a liquid phase, while nitrogen and oxygen are far apart and randomly arranged indicating a gas phase.

17. What would happen to the system if the temperature increases to 90 ^{o}C? Explain your answer and draw a new particulate representation of the system.
    Hexane would move from the liquid phase to the gas phase as we have passed the boiling point of hexane. (The sketch should include water still in the liquid phase as shown in Model 2. However, hexane, nitrogen, and oxygen will all now be in the gas phase as shown by spreading the molecules apart.)