Na

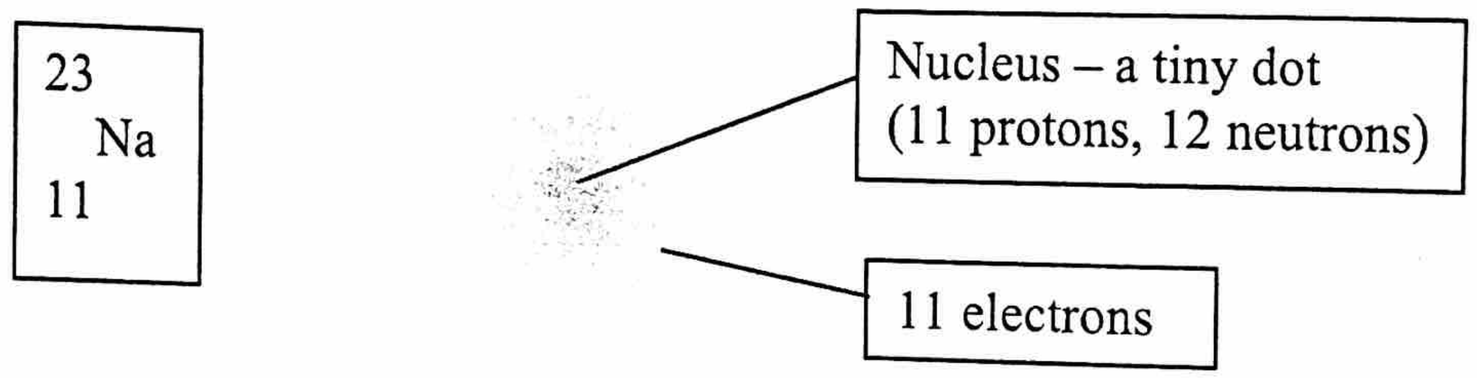
Subatomic Particles

Particle	Symbol	Relative Charge	Absolute Mass	Relative Mass
electron	e^-	-1	9.109×10^{-31} kg	0
proton	p^+	+1	1.673×10^{-27} kg	1
neutron	n^0	0	1.675×10^{-27} kg	1

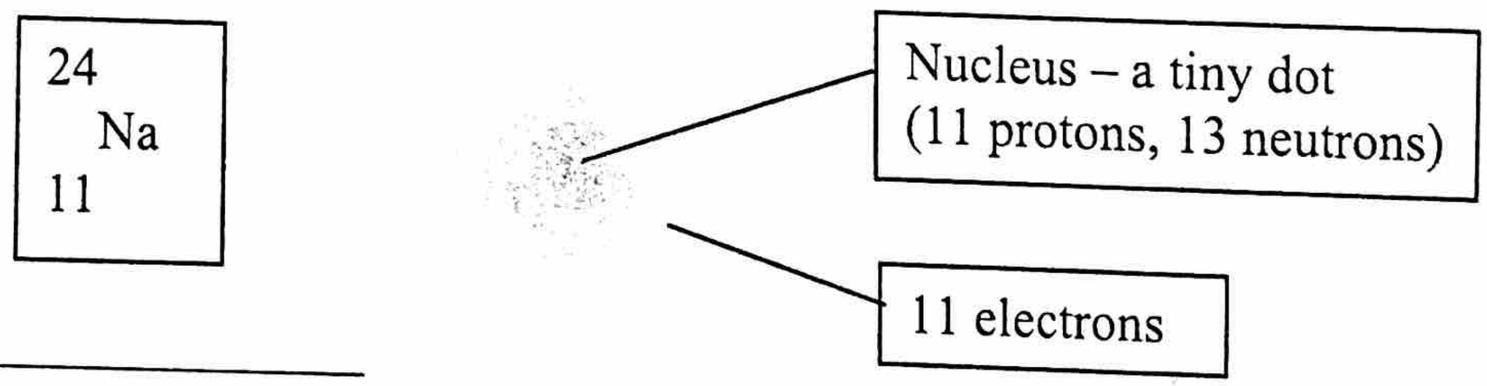
Model: Two Isotopes of Sodium

The diagrams below show representations of sodium isotopes. [Note: the diameter of an atom is about 10,000 times larger than the diameter of the atomic nucleus so the relative sizes of the atom and the nucleus are not accurately depicted in these diagrams.]

Isotope 1



Isotope 2



Key Questions

1. What information is provided by the atomic number, Z?

# of protons

2. What information is provided by the mass number, A?

protons + neutrons

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2

3. What is the relationship between the number of protons and the number of electrons in an atom?

they are the same

4. Because of the relationship between the number of protons and number of electrons in an atom, what is the electrical charge of an atom?

0

5. Where are the protons and neutrons located in an atom?

nucleus

6. What do the two sodium isotopes shown in the model have in common with each other?

# of protons

7. How do the two sodium isotopes shown in the model differ from each other?

# of neutrons + mass #

8. What distinguishes an atom of one element from an atom of another element?

# of protons

Exercises

1. Describe the similarities between $^{35}_{17}Cl$, and $^{37}_{17}Cl$.

symbol, # of protons

2. Describe the differences between $^{35}_{17}Cl$, and $^{37}_{17}Cl$.

mass # + # of neutrons

3. Write the atomic symbols for two isotopes of carbon, C, one with 6 neutrons and the other with 7 neutrons.

$^{12}_{6}C$ $^{13}_{6}C$

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4. Use a periodic table to fill in the missing information in the following table.

Name	Symbol	Atomic Number Z	Mass Number A	Number of Neutrons	Number of Electrons
oxygen	$^{16}_{8}O$	8	16	8	8
nitrogen	$^{14}_{7}N$	7	14	7	7
Sulfur	$^{34}_{16}S$	16	34	18	16
hydrogen	$^{2}_{1}H$	1	2	1	1
hydrogen	$^{3}_{1}H$	1	3	2	1
magnesium	$^{24}_{12}Mg$	12	24	12	12
magnesium	$^{25}_{12}Mg$	12	25	13	12
uranium	$^{238}_{92}U$	92	238	146	92
krypton	$^{84}_{36}Kr$	36	84	48	36

Problems

1. The radius of a Cl nucleus is 4.0 fm, and the radius of a Cl atom is 100 pm. (1 fm = 1 x 10^{-15} m; 1 pm = 1 x 10^{-12} m).How many times larger is the diameter of the Chlorine atom than the diameter of the Chlorine nucleus?

2. Identify two objects that have this same ratio of lengths.

3. How many times larger is the volume of the atom than the volume of the nucleus?

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Basic Atomic Structure Worksheet

1. The 3 particles of the atom are:
   a. protons
   b. neutrons
   c. electrons

   Their respective charges are:
   a. +
   b. 0
   c. −

2. The number of protons in one atom of an element determines the atom's identity, and the number of electrons determines the charge of the element.

3. The atomic number tells you the number of protons in one atom of an element. It also tells you the number of electrons in a neutral atom of that element. The atomic number gives the "identity" of an element as well as its location on the periodic table. No two different elements will have the same atomic number.

4. The average atomic mass of an element is the average mass of an element's naturally occurring atom, or isotopes, taking into account the percentage of each isotope.

5. The mass # of an element is the total number of protons and neutrons in the nucleus of the atom.

6. The mass number is used to calculate the number of neutrons in one atom of an element. In order to calculate the number of neutrons you must subtract the protons from the mass #.

7. Give the symbol of and the number of protons in one atom of:

   Lithium Li 3
   Iron Fe 26
   Oxygen O 8
   Krypton Kr 36
   Bromine Br 35
   Copper Cu 29
   Mercury Hg 80
   Helium He 2

8. Give the symbol of and the number of electrons in a neutral atom of:

   Uranium U 92
   Boron B 5
   Chlorine Cl 17
   Iodine I 53
   Xenon Xe 54

9. Give the symbol of and the number of neutrons in one atom of:

   (Mass numbers are ALWAYS whole numbers...show your calculations)

   Barium Ba 81
   Carbon C 6
   Fluorine F 10
   Europium Eu 89
   Bismuth Bi 126
   Hydrogen H 0
   Magnesium Mg 12
   Mercury Hg 121

10. Name the element which has the following numbers of particles:

a. 26 electrons, 29 neutrons, 26 protons Iron

b. 53 protons, 74 neutrons Iodine

c. 2 electrons (neutral atoms) Helium

d. 20 protons calcium

e. 86 electrons, 125 neutrons, 82 protons lead

f. 0 neutrons hydrogen

11. If you know ONLY the following information can you ALWAYS determine what the element is? (Yes/No)

a. Number of protons yes

b. Number of neutrons no

c. Number of electrons in a neutral atom yes

d. Number of electrons no

12. Fill in the missing items in the table below.

NAME	SYMBOL	Z	A	# PROTONS	# ELECTRONS	# NEUTRONS	ISOTOPIC SYMBOL
a. sodium	Na	11	23	11	11	12	$^{23}_{11}Na$
b. chlorine	Cl	17	35	17	18	18	$^{35}_{17}Cl^-$
c. Potassium	K	19	39	19	19	20	$^{39}_{19}K$
d. phosphorus	P	15	31	15	15	16	$^{31}_{15}P$
e. Iron	Fe	26	56	26	24	30	$^{56}_{26}Fe^{+2}$
f. Iodine	I	53	127	53	53	74	$^{127}_{53}I$
g. Silver	Ag	47	108	47	47	61	$^{108}_{47}Ag$
h. Krypton	Kr	36	84	36	36	48	$^{84}_{36}Kr$
i. Tungsten	W	74	184	74	74	110	$^{184}_{74}W$
j. Copper	Cu	29	64	29	29	35	$^{64}_{29}Cu$
k. Indium	In	49	115	49	49	66	$^{115}_{49}In$
l. Gold	Au	79	197	79	78	118	$^{197}_{79}Au^{+1}$
m. Sulfur	S	16	32	16	18	16	$^{32}_{16}S^{-2}$

Atomic Structure

Symbol	Atomic Number	Mass Number	Number of Protons	Number of Neutrons	Number of Electrons	Charge
$^{108}Ag^{+1}$	47	108	47	61	46	+1
$^{56}Fe^{+3}$	26	56	26	30	23	+3
$^{80}Br^{-1}$	35	80	35	45	36	-1
$^{198}_{79}Au^{+3}$	79	198	79	119	76	+3
^{206}Pb	82	206	82	124	82	0
^{19}F	9	19	9	10	9	0
$^{84}_{37}Rb$	37	84	37	47	37	0
^{127}I	53	127	53	74	53	0
$^{9}Be^{+2}$	4	9	4	5	2	+2
$^{16}O^{-2}$	8	16	8	8	10	-2
$^{196}Pt^{+4}$	78	196	78	118	74	+4
$^{91}Zr^{+2}$	40	91	40	51	38	+2
^{59}Ni	28	59	28	31	28	0
$^{34}_{17}Cl^{-}$	17	34	17	17	18	-1
^{118}Sn	50	118	50	68	50	0
$^{32}S^{-2}$	16	32	16	16	18	-2
$^{58}Sr^{+2}$	38	58	38	20	36	+2
$^{40}_{19}K$	19	40	19	21	19	0
^{223}Fr	87	223	87	136	87	0

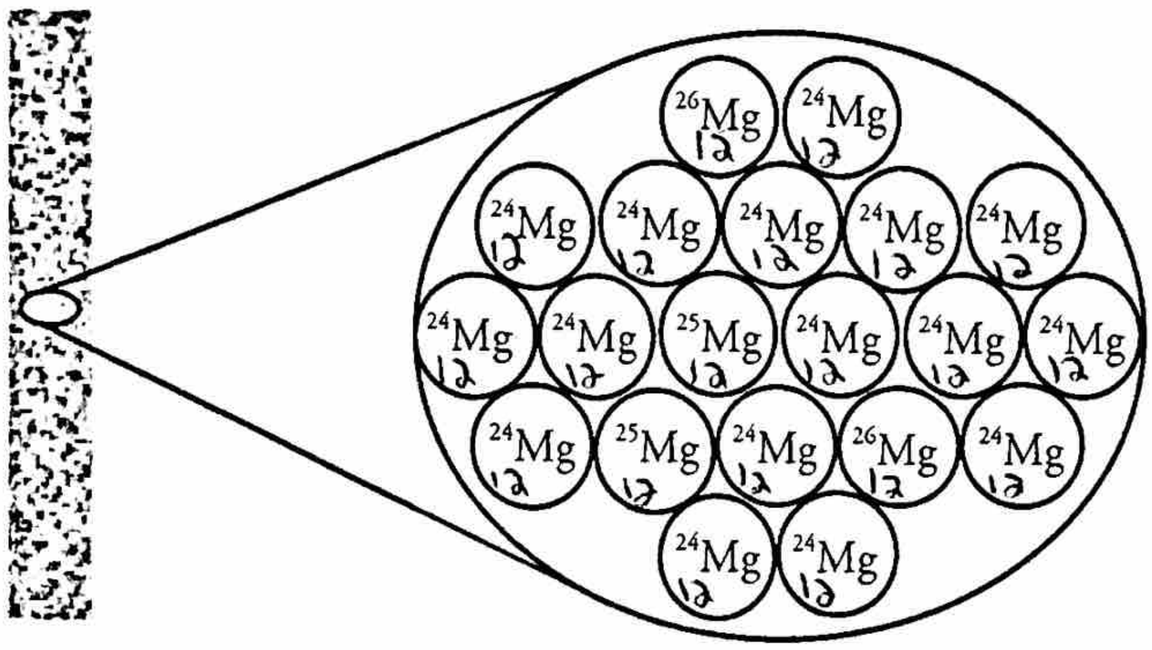
Average Atomic Mass

How are the masses on the periodic table determined?

Why?

Most elements have more than one naturally occurring isotope. As you learned previously, the atoms of those isotopes have the same atomic number (number of protons), making them belong to the same element, but they have different mass numbers (total number of protons and neutrons) giving them different atomic masses. So which mass is put on the periodic table for each element? Is it the most common isotope's mass? The heaviest mass? This activity will help answer that question.

Model 1 – A Strip of Magnesium Metal



1. Write in the atomic number for each Mg atom in Model 1.

2. What are the mass numbers of the naturally occurring isotopes of magnesium shown in Model 1?

   24, 25, 26

3. Do all of the atoms of magnesium in Model 1 have the same atomic mass? Explain.

   No. They differ from 24 - 26.

4. For the sample of 20 atoms of magnesium shown in Model 1, draw a table indicating the mass numbers of the three isotopes and the number of atoms of each isotope present.

mass #	quantity
24	16
25	2
26	2

5. Which isotope of magnesium is the most common in Model 1?

   $^{24}_{12}Mg$

6. Based on Model 1 and the table you created in Question 4, for every 10 atoms of magnesium, approximately how many atoms of each isotope will be found?

   24: 8 25: 1 26: 1

10

Model 2 – Natural Abundance Information for Magnesium

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{24}Mg	78.99	23.9850
^{25}Mg	10.00	24.9858
^{26}Mg	11.01	25.9826

7. Consider the natural abundance information given in Model 2.

   a. Calculate the expected number of atoms of each isotope that will be found in a sample of 20 atoms of Mg. *Hint:* The number of atoms must be a whole number!

   24 Mg → 16 25 Mg → 2 26 Mg → 2

   b. Is Model 1 accurate in its representation of magnesium at the atomic level? Explain.

   yes because they are in the correct ratio

8. If you could pick up a single atom of magnesium and put it on a balance, the mass of that atom would most likely be _____ amu. Explain your reasoning.

   23.9850 amu because it is most abundant, so we are more likely to pick 24 Mg

9. Refer to a periodic table and find the box for magnesium.

   a. Write down the decimal number shown in that box.

   24.31

   b. Does the decimal number shown on the periodic table for magnesium match any of the atomic masses listed in Model 2?

   No

10. The periodic table does not show the atomic mass of every isotope for an element.

    a. Explain why this would be an impractical goal for the periodic table.

    Because all the elements have many naturally occuring isotopes

    b. Is it important to the average scientist to have information about a particular isotope of an element? Explain.

    No because scientists can't pick out which specific atom they are getting.

11. What would be a practical way of showing the mass of magnesium atoms on the periodic table given that most elements occur as a mixture of isotopes?

    average

12. Propose a possible way to calculate the average atomic mass of 100 magnesium atoms. Your answer may include a mathematical equation, but it is not required.

    multiple the mass by the percent it occurs and divide by 100

STOP

11

this is how we find average atomic mass

Model 3 – Proposed Average Atomic Mass Calculations

Mary's Method

$$\frac{(78.99)(23.9850 \text{ amu}) + (10.00)(24.9858 \text{ amu}) + (11.01)(25.9826 \text{ amu})}{100} = \underline{24.31}$$

Jack's Method

$(0.7899)(23.9850 \text{ amu}) + (0.1000)(24.9858 \text{ amu}) + (0.1101)(25.9826 \text{ amu}) = \underline{24.31}$

Alan's Method

$$\frac{23.9850 \text{ amu} + 24.9858 \text{ amu} + 25.9826 \text{ amu}}{3} = \underline{24.98}$$

13. Complete the three proposed calculations for the average atomic mass of magnesium in Model 3.

14. Consider the calculations in Model 3.

a. Which methods shown in Model 3 give an answer for average atomic mass that matches the mass of magnesium on the periodic table?

Mary's and Jack's method

b. Explain why the mathematical reasoning was incorrect for any method(s) in Model 3 that did not give the correct answer for average atomic mass (the one on the periodic table).

Alan's method did not take into account how often the isotopes occur.

c. For the methods in Model 3 that gave the correct answer for average atomic mass, show that they are mathematically equivalent methods.

$$\frac{78.99}{100} = 0.7899$$

15. Use one of the methods in Model 3 that gave the correct answer for average atomic mass to calculate the average atomic mass for oxygen. Isotope information is provided below. Show all of your work and check your answer against the mass listed on the periodic table.

Isotope	Natural Abundance on Earth (%)	Atomic Mass (amu)
^{16}O	99.76	15.9949
^{17}O	0.04	16.9991
^{18}O	0.20	17.9992

$(.9976 \times 15.9949) + (.0004 \times 16.9991) + (0.0020 \times 17.9992)$

$= 15.9993$ amu

STOP

Read This!

Recall that all isotopes of an element have the same physical and chemical properties, with the exception of atomic mass (and for unstable isotopes, radioactivity). Therefore, the periodic table lists a weighted **average atomic mass** for each element. In order to calculate this quantity, the natural abundance and atomic mass of each isotope must be provided.

16. Consider the individual atomic masses for magnesium isotopes given in Model 2.

    a. Which isotope has an atomic mass closest to the average atomic mass listed on the periodic table?

    ^{24}Mg

    b. Give a mathematical reason for your answer to part *a*.

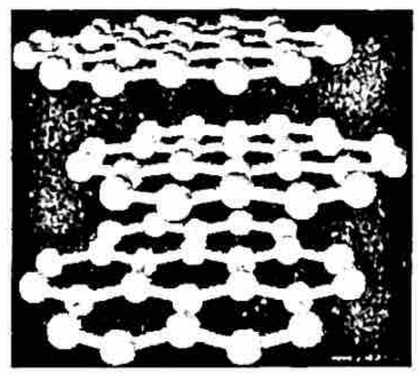
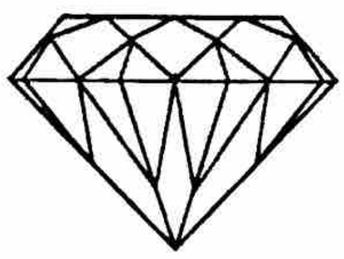
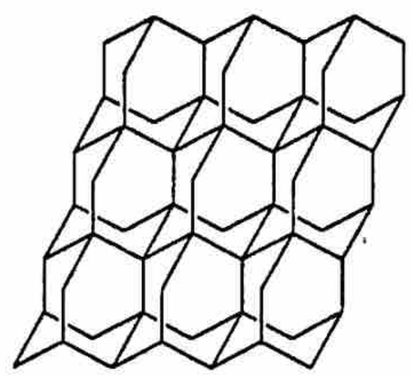
    Since we are multiplying it by the occurance it should be closest to the largest quantity

17. Boron has two naturally occurring isotopes: boron-10 and boron-11. Which isotope is more abundant on Earth? Use grammatically correct sentences to explain how your group determined the answer.

    "B is more abundant on Earth since the average atomic mass is closer to 11 than 10.

Extension Questions

Model 4 – Allotropes of Carbon

Natural Sample	Properties	Structure	Composition
 Graphite	Black Soft Conductive		98.89% Carbon-12 1.11% Carbon-13
 Diamond	Colorless Very hard Insulator		98.89% Carbon-12 1.11% Carbon-13

18. Consider the information about carbon provided in Model 4.

    a. Are diamonds and graphite made from the same element?

    yes

    b. Can the existence of isotopes explain the difference in properties between diamond and graphite? Explain.

    No because the composition of both are the same

    c. Propose an explanation for the difference in properties between diamond and graphite.

    the way the atoms allign themselves (structure) could be the difference

19. O_2 and O_3 (ozone) are allotropes of oxygen. Buckminsterfullerene (C_{60}) is another allotrope of carbon. Based on these statements and the information in Model 4, propose a definition for **allotrope**.

    An allotrope is different physical forms an element can exist in

20. Two common forms of phosphorus are red and white. Red phosphorus is fairly stable at room temperature in air, but white phosphorus can ignite easily when exposed to air. Is this difference in properties due to the existence of different isotopes of phosphorus or different allotropes? Explain.

    different allotropes because all phosphorus should have the same composition

Average Atomic Mass Classwork

1. Answer the following questions using the data below:

Isotope	Mass (amu)	% Abundance
1	31.972	95.0
2	32.971	0.76
3	33.967	4.22
4	35.967	0.014

a. What is the most common isotope of the unknown element?

Isotope 1

b. Calculate the average atomic mass of the unknown element.

(.95 x 31.972) + (0.0076 x 32.971) + (.0422 x 33.967) +

(.00014 x 35.967)

= 32.062 amu

c. Use your periodic table to identify the unknown element.

Sulfur

d. What is the atomic number of this element? 16

e. This atom forms an ion with a charge of –2. Write the isotopic symbol for the most common isotope of this element.

$^{32}_{16}S^{-2}$

2. Copper has two naturally occurring isotopes with mass numbers 63 and 65. The relative abundances and atomic masses of these isotopes are as follows: 69.2% for mass= 62.93 amu and 30.8% for mass=64.93amu. Calculate the average atomic mass for copper.

(.692 x 62.93) + (.308 x 64.93)

= 63.55 amu

3. Samples of an unknown element X were collected and their masses were recorded. Use the information presented in the data table to answer the following questions:

Isotope	Mass(amu)	% Abundance
1	37.765	9.67
2	39.056	78.68
3	40.003	11.34
4	41.060	0.31

a. Determine the mass number for each isotope of element X.

1 → 38 4 → 41
2 → 39
3 → 40

b. What is the most common isotope of element X?

39 X (isotope #2)

c. Calculate the average atomic mass of elements X.

(.0967 x 37.765) + (.7868 x 39.056) + (.1134 x 40.003) + (.0031 x 41.060)

= 39.045 amu

d. Use your periodic table to identify element X.

K

e. What is the atomic number of this element?

19

f. This atom forms an ion with a charge of 1+. Write the isotopic symbol for the most common isotope of this element.

$^{39}_{19}K^{+1}$

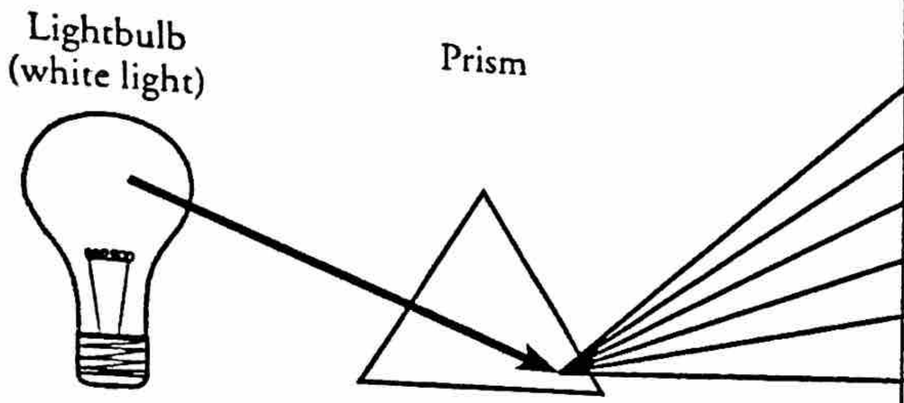
Electron Energy and Light

How does light reveal the behavior of electrons in an atom?

Why?

From fireworks to stars, the color of light is useful in finding out what's in matter. The emission of light by hydrogen and other atoms has played a key role in understanding the electronic structure of atoms. Trace materials, such as evidence from a crime scene, lead in paint or mercury in drinking water, can be identified by heating or burning the materials and examining the color(s) of light given off in the form of bright-line spectra.

Model 1 – White Light



Color	Photon Energy ($\times 10^{-21}$) (J)	Wavelength Range (nm)	Speed (m/s)
Reds	269–318	625–740	3.00×10^8
Oranges	318–337	590–625	3.00×10^8
Yellows	337–352	565–590	3.00×10^8
Greens	352–382	520–565	3.00×10^8
Blues	382–452	440–520	3.00×10^8
Violets	452–523	380–440	3.00×10^8

1. Trace the arrows in Model 1 and shade in the table with colored pencils where appropriate.
2. What happens to white light when it passes through a prism?

   Splits into light of many different colors

3. Why are the color labels in the table in Model 1 plural (*i.e.*, "Reds" rather than "Red")?

   different shades of red so they have different energies and wavelengths

4. Do all colors of light travel at the same speed?

   yes (3.00×10^8 m/s)

5. Do all colors of light have the same energy? If no, which colors have the highest energy and the least energy, respectively?

   No → violet has the highest, red has the lowest

6. Consider the light illustrated in Model 1.

   a. Which color corresponds to the longest wavelengths?

   reds

   b. Which color corresponds to the shortest wavelengths?

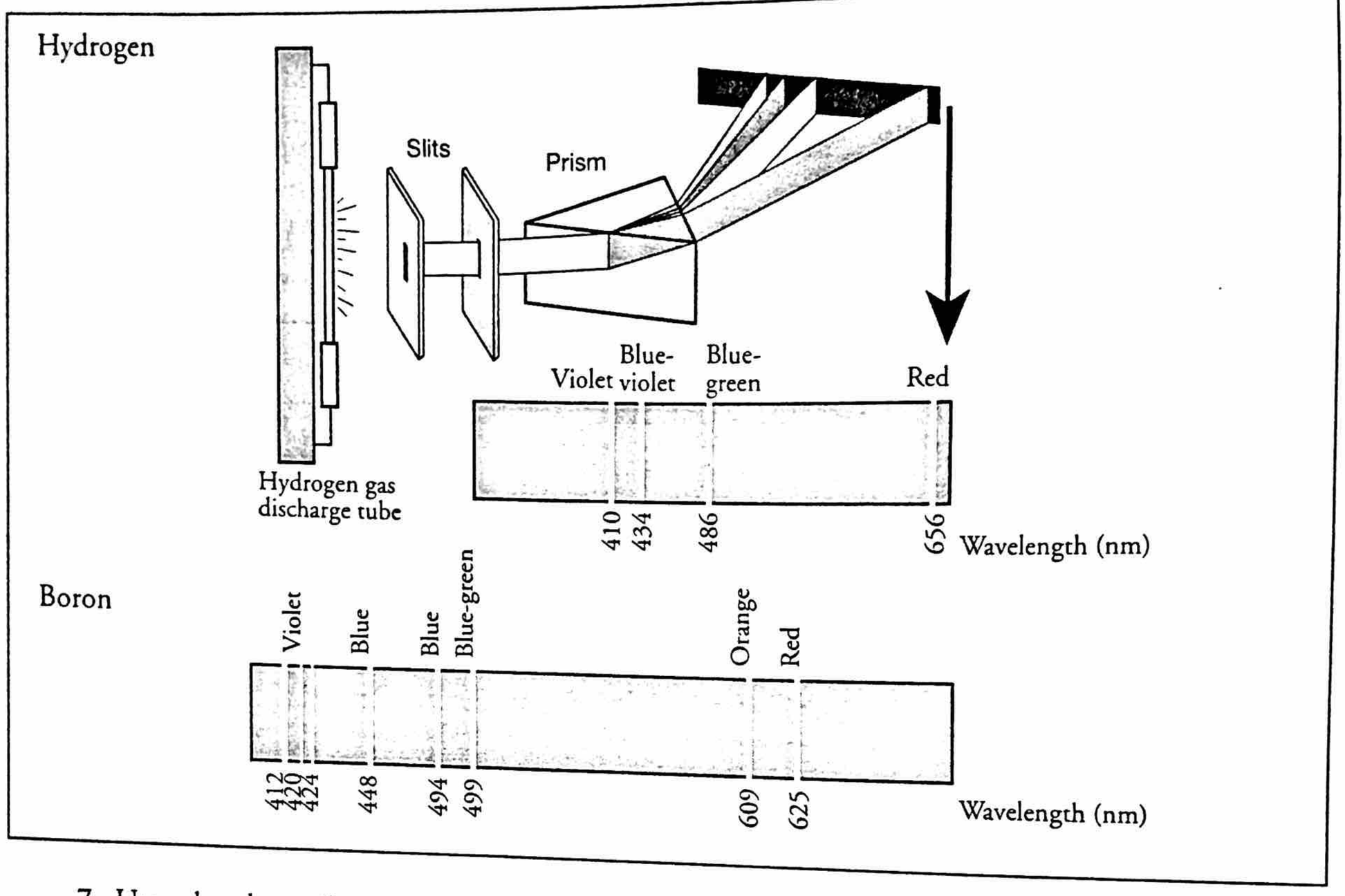
   violets

   c. Write a sentence that describes the relationship between wavelength and energy of light.

   the longer the wavelength the less energy (inverse relationship)

STOP

Model 2 – Emission Spectra for Hydrogen and Boron Atoms



7. Use colored pencils to color the hydrogen and boron spectral lines within their respective spectra in Model 2.

8. List the spectral lines for hydrogen gas by color and corresponding wavelength.

violet - 410nm, Blue-violet - 434nm, Blue-green - 486nm, Red - 656nm

9. The spectral lines for boron were produced using the same method as hydrogen. List three of the colors and corresponding wavelengths for boron's spectral lines as its light passes through a prism.

Violet (nm)	Blue (nm)	Blue-green (nm)	Orange (nm)	Red (nm)
410	448	499	609	625
420	494			
424				

10. Consider the hydrogen spectrum in Model 2.

a. Which color of light corresponds to the shortest wavelength?

violet

b. Which color of light corresponds to the longest wavelength?

Red

18

11. Consider the hydrogen spectrum in Model 2.

a. Which color of light has the most energy?

violet

b. Which color of light has the least energy?

red

12. Does a gas discharge tube filled with boron emit the same wavelengths of light as a tube filled with hydrogen? Use evidence from Model 2 to support your answer.

No → showed different wavelengths

13. "The spectral lines for atoms are like fingerprints for humans." How do the spectral lines for hydrogen and boron support this statement?

the spetral lines are unique to the element

Circle the appropriate word to complete each statement in Questions 14–17.

14. Electrons and protons (attract/repel) each other.

15. As an electron gets closer to the nucleus the (attraction/repulsion) to the nucleus gets (stronger/weaker).

16. For an electron to move from an energy level close to the nucleus to an energy level far from the nucleus it would need to (gain/lose) energy.

17. For an electron to move from an energy level far from the nucleus to an energy level close to the nucleus it would need to (gain/lose) energy.

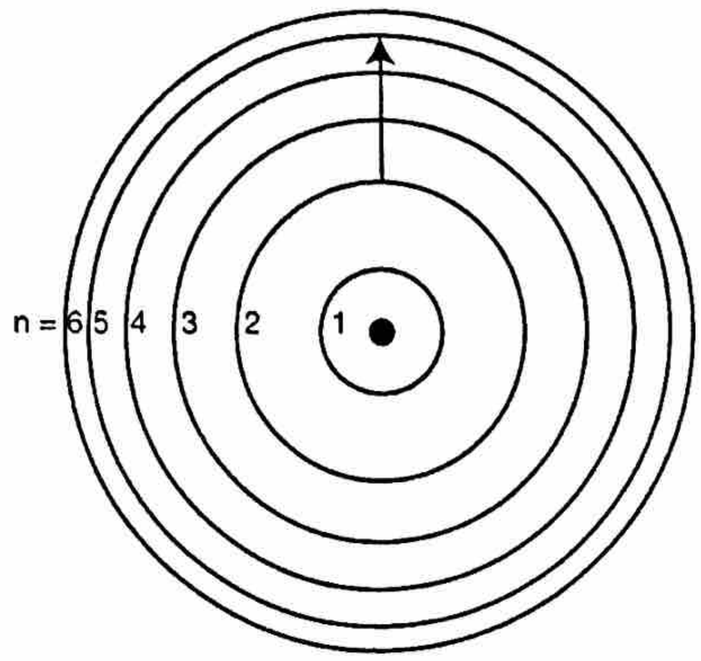
STOP

Read This!

Niels Bohr modified Rutherford's Nuclear Atom model to explain how light interacted with the electrons in an atom to produce spectral lines. His model included electrons orbiting the nucleus at specific energy levels. Electrons absorb energy from various sources (electricity) when they move from lower energy levels (ground state) to higher energy levels (excited states). Energy is released as electrons return to their lower energy levels.

18. Is energy absorbed or released for the electron transition shown in the diagram to the right? Explain.

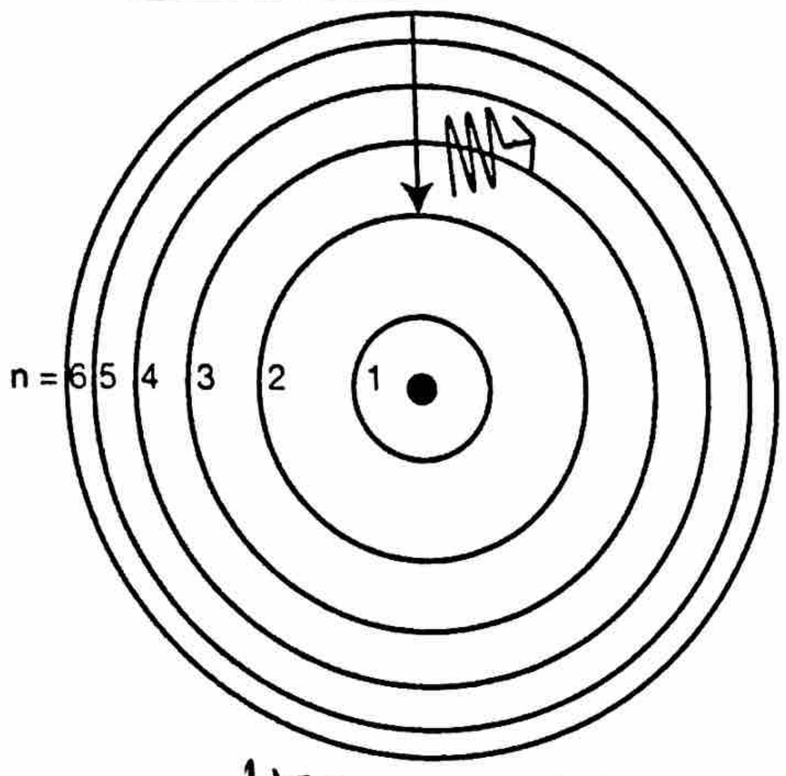
absorbed b/c the electron is going to a higher energy level so it needs to gain energy



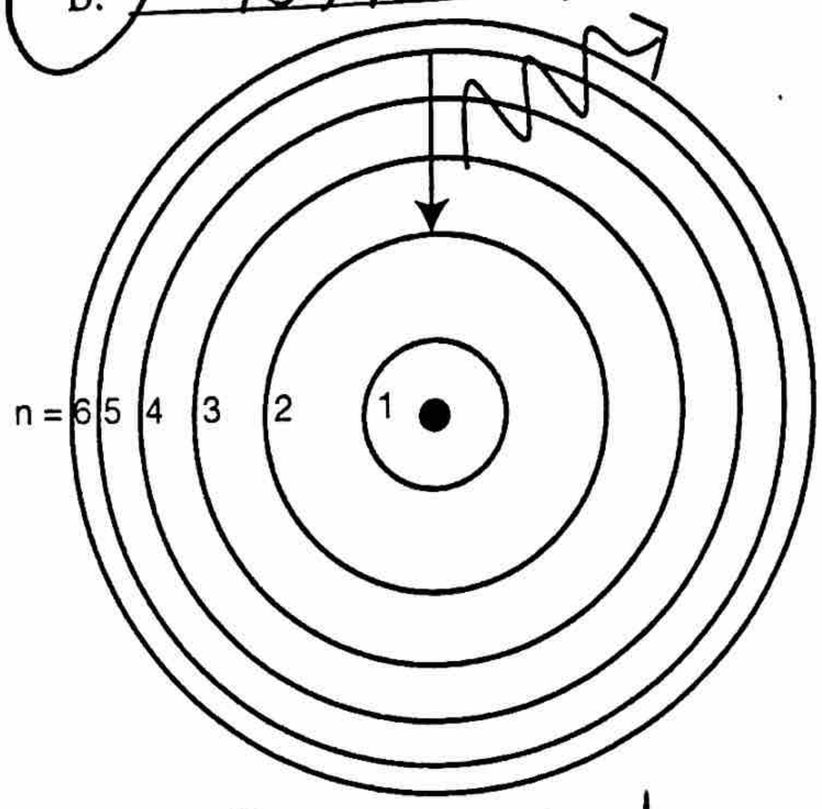
19

Model 3 – Bohr Model of a Hydrogen Atom

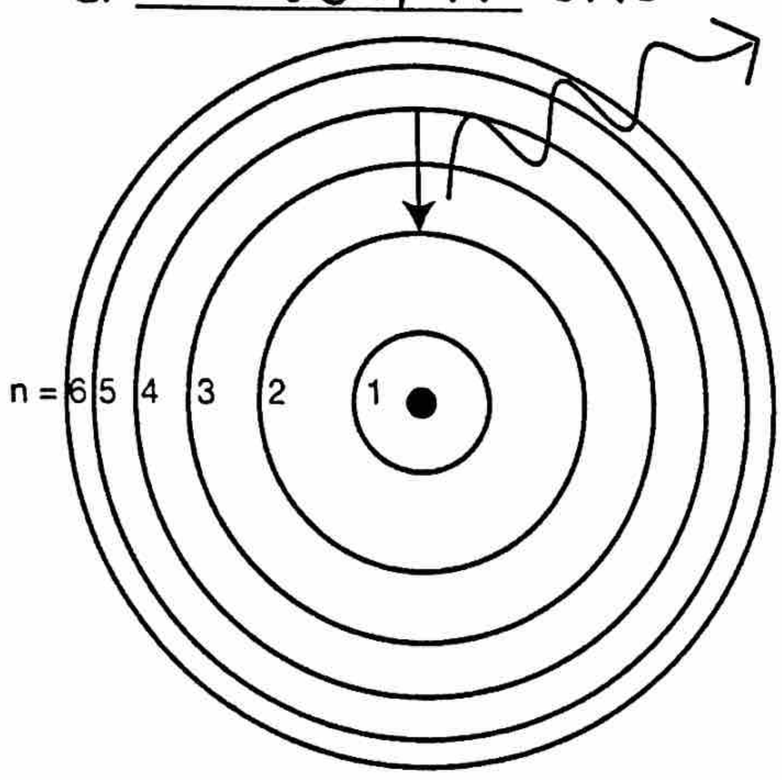
A. 410 nm - violet



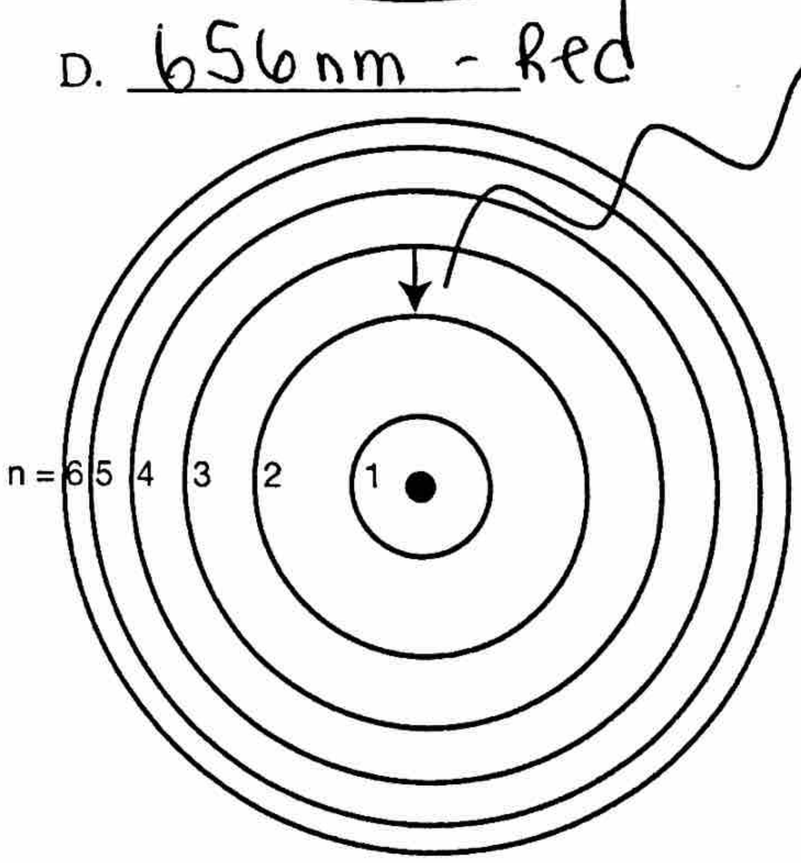
B. 434nm - blue



C. 486nm blue



D. 656nm - Red



19. Identify the drawing in Model 3 that depicts a hydrogen atom with an electron moving from energy level 5 to energy level 2. Refer to Models 1 and 2 for the following questions.

a. Label the picture with "n=5 to n=2" and list the corresponding color of light emitted. 434nm Blue

b. This electron transition (absorbs/releases) energy.

c. This electron moves from a (lower/higher) energy state to a (lower/higher) energy state.

d. Is light absorbed or released in the electron transition?

released

20

20. Label the remaining drawings in Model 3 with the electron transitions that are occurring (n=? to n=?), the wavelengths and corresponding colors as given in example A in Model 3. See Model 2 in order to identify the color of spectral lines produced in each of the hydrogen atom electron transitions shown in Model 3. Use colored pencils to trace the light wave in each of the four pictures with the appropriate color.

21. Consider the electron transitions in Model 3.

a. Which of the electron transitions involves the most energy?

6 → 2 (violet)

b. Explain why this transition involves the most energy based on your understanding of the attractive forces between the electrons and protons in the atom.

Since the electron is being pulled toward the nucleus the further down it goes, the more energy that needs to be released

22. Explain why a single atom of hydrogen cannot produce all four hydrogen spectral lines simultaneously.

it only has one electron

23. If Question 22 is true, how can we see all four colors from a hydrogen gas discharge tube simultaneously?

there has to be more than one hydrogen atom, or if there is energy flow through the tube the same electron can keep being excited and relaxing

Extension Questions

24. The hydrogen spectral lines in Model 2 are only the wavelengths of light that are in the visible range and therefore "seen" by the naked eye. However, many other wavelengths can be detected with special equipment.

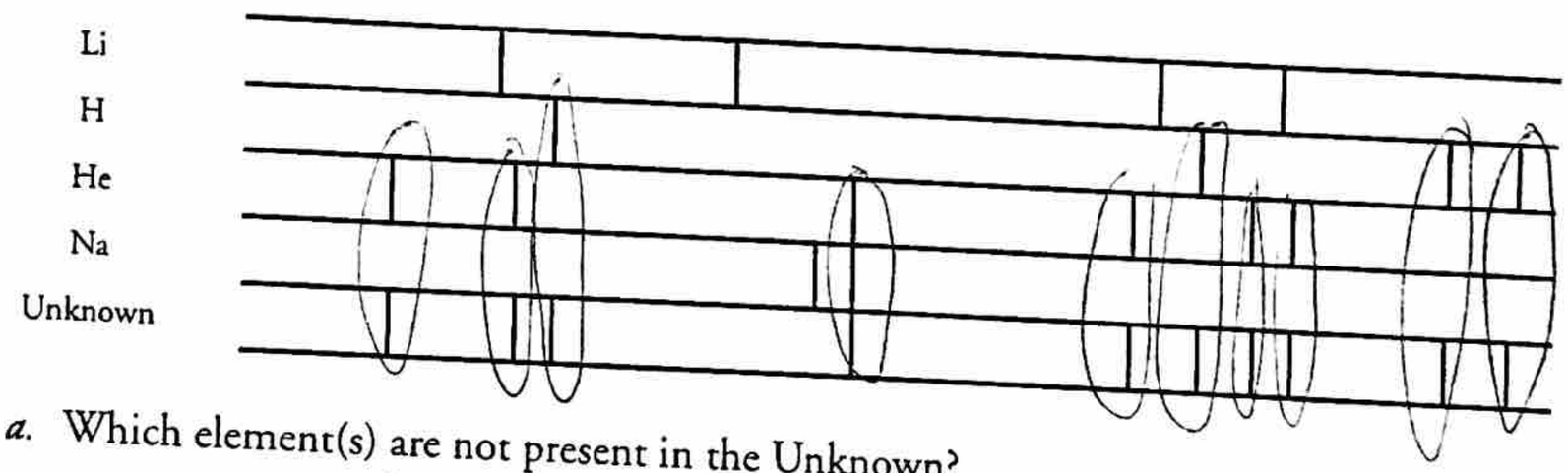
    a. Propose a hydrogen electron transition that involves light with a wavelength in the ultraviolet (UV) range (10–400 nm).

    2→1 , 3→1, 4→1

    b. Propose a hydrogen electron transition that involves light with a wavelength in the infrared (IR) range (1000–106 nm).

    4→3, 5→3, 6→3

25. Below are diagrams for the bright line spectra of four elements and the spectrum of a mixture of unknown gases.



    a. Which element(s) are not present in the Unknown?

    Li

    b. Which element(s) are in the Unknown?

    H, He, Na

26. Model 2 shows the emission spectra for hydrogen and boron. Scientists can also record the absorption spectra for elements. Propose how this might be done, and what the absorption spectra of hydrogen and boron would look like.

Bohr's Model of the Hydrogen Atom

1. What wavelength of light is emitted when an electron relaxes from n=4 to n=2?

   486 nm

2. What wavelength of light is emitted when an electron relaxes from n=5 to n=3?

   1282 nm

3. An electron moves from n=3 to n=5. Is energy emitted or absorbed?

   absorbed

4. An electron moves from n=2 to n=1. Is energy emitted or absorbed?

   emitted

5. What electron transformation(s) cause(s) red light to be emitted?

   Red light is 7.0×10^{-7} m → 6.5×10^{-7} m → 700 - 650 nm n=3 to n=2

6. What electron transformation(s) cause(s) UV light to be emitted?

   n=3 to n=1, n=2 to n=1, n=4 to n=1

always convert nm → m to use in a problem

Light and Energy Class Work

Complete the following problems on your own paper.

Use your reference packet!

Useful Equations	
$c = \lambda v$	$c = 2.998 \times 10^8$ m/s
$E = hv$	$h = 6.626 \times 10^{-34}$ J*s
$1m = 1 \times 10^9$ nm	

1. Draw the Bohr Models for Hydrogen, Nitrogen & Aluminum. Don't worry about this one

2. Light with a wavelength of 525nm is green. Calculate the frequency for this green light.

$525nm \left| \frac{1\ m}{1 \times 10^9 nm} \right. = 5.25 \times 10^{-7} m$ $\quad \nu = \frac{(2.998 \times 10^8 m/s)}{5.25 \times 10^{-7} m} = 5.71 \times 10^{14}$ Hz

3. Calculate the energy (in J) for a photon of green light from the previous question.

$E = (6.626 \times 10^{-34} Js)(5.71 \times 10^{14} Hz)$

$= 3.78 \times 10^{-19} J$

4. UV radiation has a frequency of 6.8×10^{15} 1/s. What is the energy (in J) for a photon of UV light?

$E = (6.626 \times 10^{-34} Js)(6.8 \times 10^{15} Hz)$

$= 4.5 \times 10^{-18} J$

5. What is the wavelength and frequency of a photon ~~with an energy of 1.4 × 10-21 J~~?

$E = h\nu$

$1.4 \times 10^{-21} J = 6.626 \times 10^{-34} Js \cdot \nu$ $\quad \nu = 2.1 \times 10^{12}$ Hz

$\lambda = \frac{(2.998 \times 10^8 m/s)}{2.1 \times 10^{12} Hz}$

$\lambda = 1.4 \times 10^{-4}$ m

6. A ruby laser produces red light that has a wavelength of 500 nm. Calculate its energy in joules (J)

$500nm \left| \frac{1\ m}{1 \times 10^9 nm} \right. = 5 \times 10^{-7} nm$ $\quad \nu = \frac{(2.998 \times 10^8 m/s)}{5 \times 10^{-7} m} = 6 \times 10^{14}$ Hz

$E = (6.626 \times 10^{-34} Js)(6 \times 10^{14} Hz) = 4 \times 10^{-19} J$

7. As frequency increases, wavelength decrease. Explain why.

the shorter the length of the wavelength, the more often that it can complete a wavelength

8. What is the wavelength of light emitted as an electron moves from n=5 to ~~n=1~~ n=2 In meters?

$434 nm \left| \frac{1\ m}{1 \times 10^9 nm} \right. = 4.34 \times 10^{-7} m$

9. What is the energy of light for the previous question.

$\nu = c/\lambda = \frac{(2.998 \times 10^8 m/s)}{(4.34 \times 10^{-7} m)} = 6.91 \times 10^{14}$ Hz

$E = (6.626 \times 10^{-34} Js)(6.91 \times 10^{14} Hz)$

$E = 4.58 \times 10^{-19} J$

10. What kind of light is emitted?

visible

11. Which color of visible light has the longest wavelength? The shortest?

a. What are the frequencies that correspond to these colors of light?

Red has the longest

$\nu = \frac{(2.998 \times 10^8 m/s)}{(7.0 \times 10^{-7} m)} = 4.3 \times 10^{14}$ Hz

Violet has the shortest

$\nu_2 = \frac{(2.998 \times 10^8 m/s)}{(4.0 \times 10^{-7} m)} = 7.5 \times 10^{14}$ Hz

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Wavelength, Frequency, Speed & Energy Worksheet

$c = \lambda \nu$ $\quad \nu = c / \lambda$ $\quad \lambda = c / \nu$ $\quad E = h\nu$ $\quad E = h\, c/\lambda$

c = speed of light (3.0×10^{8} m/s)
λ = wavelength
ν = frequency
E = energy
h = Planck's constant (6.6262×10^{-34} J•s)

1. Calculate the **λ** given the **ν** of radiation is $5.10 \times 10^{14}\ s^{-1}$

$\lambda = \frac{(2.998 \times 10^{8}\ m/s)}{(5.10 \times 10^{14}\ Hz)} = 5.88 \times 10^{-7}\ m$

2. Calculate the **frequency** of red light with **λ** = 6.50×10^{-7}m

$\nu = \frac{(2.998 \times 10^{8}\ m/s)}{(6.50 \times 10^{-7}\ m)} = 4.61 \times 10^{14}\ Hz$

3. The more I shave my face, the shorter my beard is an example of a <u>inversely</u> proportional or <u>directly</u> proportional relationship? inverse

4. The more I lift weights, the stronger I become, is an example of an <u>inversely</u> proportional or <u>directly</u> proportional relationship. direct

5. The longer the wavelength, the lower the frequency, is an inverse relationship

6. Which color has the longest wavelength? Red
7. Which color has the shortest wavelength? violet
8. On the EM Spectrum, which type of wave has the longest wavelength? radio waves
9. On the EM Spectrum, which type of wave has the shortest wavelength? gamma waves

10. What is the **energy** of x- radiation with a 1×10^{-6}m **wavelength**?

$\nu = \frac{(2.998 \times 10^{8}\ m/s)}{1 \times 10^{-6}\ m} = 3 \times 10^{14}\ Hz \rightarrow E = (6.626 \times 10^{-34}\ J\cdot s)(3 \times 10^{14}\ Hz)$

$E = 2 \times 10^{-19}\ J$

11. What is the **energy** (Joules) of Violet light with a **frequency** = $7.50 \times 10^{14}\ s^{-1}$.

$E = (6.626 \times 10^{-34}\ J\cdot s)(7.50 \times 10^{14}\ Hz) = 4.99 \times 10^{-19}\ J$

12. The higher the frequency, the higher (higher / lower) the energy. This is an example of a/an direct (inverse/direct) relationship.

13. The higher the wavelength, the lower (higher / lower) the energy. This is an example of a/an inverse (inverse/direct) relationship.

14. Which color has the most energy? Violet
15. Which color has the least energy? red
16. On the EM Spectrum, which type of wave has the most energy? gamma
17. On the EM Spectrum, which type of wave has the least energy? radio

25. Calculate the **frequency** of light with **wavelength** = 2.50×10^{-7}m

$\frac{2.998 \times 10^{8} m/s}{2.50 \times 10^{-7} m} = 1.20 \times 10^{15} Hz$

26. What is the **energy** of cell phone radiation with a 1m **wavelength?**

$\frac{2.998 \times 10^{8} m/s}{1 m} = 2.998 \times 10^{8} Hz$

$E = (6.626 \times 10^{-34} Js)(2.998 \times 10^{8} Hz)$

$= 2 \times 10^{-25} J$

27. What is the **energy** (Joules) of Violet light with a **frequency** = $7.50 \times 10^{14} s^{-1}$.

$E = (6.626 \times 10^{-34} Js)(7.50 \times 10^{14} Hz)$

$E = 4.97 \times 10^{-19} J$

28. The formula $\lambda = h/mv$ stated that it was now possible to calculate the _____ of an electron given its mass and velocity.

29. The **height** of the wave_____

30. The **distance** between two crests_____

31. The number of **cycles per second**_____

32. The primary characteristics of waves are _____, _____, _____

33. List the types of electromagnetic radiation:

radio waves, microwaves, infrared, visible,
UV, x-rays, gamma rays,

34. photons are: the light given off when an electron goes from the excited to ground state

35. The dual nature of light deals with light as wave and light as particle:

36. Einstein used the *photoelectric effect* to prove that light has _____.

37. Another name for the Quantum Mechanical Model is the electron cloud model

38. In the Quantum Mechanical Model, 100% percent of electrons are predicted to be located in the electron cloud

39. When absorbed energy, electrons go from the ground state to the excited state. As they return to the ground state, they release their energy in the form of: light

40. According to quantum mechanics, subatomic particles move in wave-like motions:

41. Red color _____ all colors _____ its own.

42. Which color of light has the **most** energy: violet

Why? shortest wavelength → highest frequency

43. Which color of light has the **least** energy: red

Why? longest wavelength → lowest frequency

44. Which color of light has the **highest** frequency: violet

45. Which color of light has the **longest** wavelength? red

46. Violet light has more energy than red light because .....

it has a higher frequency

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