Worksheet- Band of Stability

Objective: Determine if an atom is "stable", "unstable (aka radioactive)", or "does not exist" based on its position on the graph below.

Background Info: Isotopes of elements found in nature are all located within the gray area on the graph below called the band of stability. Those elements found in the middle of the "band" have a very stable nucleus, while those elements on the outer edges of the band have an unstable nucleus and are said to be "radioactive". However, some combinations of protons and neutrons in the nucleus are so unstable that they cannot even exist long enough to be recognized as elements and these fall outside the band of stability.

Instructions: a) Determine the # of subatomic particles each element contains b) Locate & plot where the following atoms would be on the graph below. Label each atom after it has been plotted (ex: see Potassium-41)

<p>| | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mg</td>
<td>Nd</td>
<td>Ir</td>
<td>Br</td>
<td>U</td>
<td>Ir</td>
</tr>
<tr>
<td>24</td>
<td>142</td>
<td>195</td>
<td>81</td>
<td>238</td>
<td>191</td>
</tr>
<tr>
<td>12</td>
<td>60</td>
<td>77</td>
<td>35</td>
<td>92</td>
<td>77</td>
</tr>
</tbody>
</table>

# P= | # e= | #n =
---|---|---
12 | 60 | 82
35 | 60 | 118
77 | 92 | 146
82 | 77 | 114

Questions to Answer:
1. Did any of your atoms land outside the gray area? Explain why or why not.
   None of the atoms landed outside of the gray area; however, uranium-238 was very close to the edge. This is because all of the atoms contain a ratio of protons to neutrons that can exist in nature.

2. How can there be two different atoms of iridium? How are they different?
   They are isotopes and differ in the number of neutrons even though they have the same number of protons and are the same element.

3. Would a small atom (less than 40 protons) be found in nature if it has the same number of protons & neutrons (1:1 ratio)? Explain.
   Yes, it would fall within the band of stability.

4. Would a large atom (more than 40 protons) be found in nature if it has the same number of protons & neutrons (1:1 ratio)? Explain.
   No, it would be outside of the band of stability.

5. Two of the atoms you plotted are naturally radioactive, that is, their nuclei fall apart over time. Which two do you think they are? What is your reasoning?
   Iridium-195 and uranium-238 are both on the edge of the band of stability and so would be radioactive.

6. Imagine a chemist was trying to create an atom with 60 protons and a mass number of 155. Would this be possible? Why or why not? (SHOW where it would fall on the graph).
   This atom would not be possible because it would not fall within the band of stability.

7. If an element had 90 protons, how many neutrons would be a good number for it to have in order to be considered a stable element? What element would this be? (SHOW where it would fall on the graph).
   An atom this large would need ~1.5 neutrons for every proton to be stable. This would be 135 neutrons. This would be thorium-225.
Worksheet - Nuclear Decay

Instructions: Fill in the table below and then use it to figure out what is happening during each type of decay - alpha (α), beta (β), and gamma (γ)

<table>
<thead>
<tr>
<th>Parent</th>
<th>Particle</th>
<th>New,</th>
<th>Alpha, Beta,</th>
<th># of protons</th>
<th>Change in</th>
</tr>
</thead>
<tbody>
<tr>
<td>Isotope</td>
<td>emitted</td>
<td>Daughter</td>
<td>or gamma Decay?</td>
<td>lost or gained</td>
<td>mass number</td>
</tr>
<tr>
<td>a. 226\text{Ra} &amp; \rightarrow &amp; _2^4\text{He} &amp; + &amp; 222\text{Rn} &amp; \text{Alpha} &amp; \text{Lost 2} &amp; \text{minus 4}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. 214\text{Po} &amp; \rightarrow &amp; _2^4\text{He} &amp; + &amp; 210\text{Pb} &amp; \text{Alpha} &amp; \text{Lost 2} &amp; \text{Minus 4}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>c. 47\text{Ca} &amp; \rightarrow &amp; _-1^0\text{e} &amp; - &amp; 47\text{Sc} &amp; \text{Beta} &amp; \text{Gained 1} &amp; \text{None}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>d. 148\text{Gd} &amp; \rightarrow &amp; _2^4\text{He} &amp; + &amp; 144\text{Sm} &amp; \text{Alpha} &amp; \text{Lost 2} &amp; \text{Minus 4}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e. 14\text{C} &amp; \rightarrow &amp; _-1^0\text{e} &amp; - &amp; 14\text{N} &amp; \text{Beta} &amp; \text{Gained 1} &amp; \text{None}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>f. 148\text{Gd} &amp; \rightarrow &amp; _0^0\text{Y} &amp; + &amp; 148\text{Gd} &amp; \text{Gamma} &amp; \text{None} &amp; \text{None}</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

2. What changes take place in the nucleus when an alpha particle is emitted?
2 Protons and 2 Neutrons are lost.

3. What is the identity of an alpha particle?
Helium Nucleus

4. What changes take place in the nucleus when a beta particle is emitted?
Neutron is broken into electron and proton. Proton kept and electron released.

5. Which particle is associated with beta decay?
Electron

6. Fill in the missing parts of these nuclear reactions: (numbers & elements)

| a) 40\text{K} & \rightarrow & _-1^0\text{e} & + & 40\text{Ca} |
| b) 230\text{Th} & \rightarrow & _2^4\text{He} & +226\text{Ra} |
| c) 35\text{Si} & \rightarrow & _-1^0\text{e} & + & 35\text{P} |
| d) 238\text{U} & \rightarrow & _2^4\text{He} & +234\text{Th} |
| e) 110\text{I} & \rightarrow & _2^4\text{He} & +106\text{Sb} & + & 0\text{Y} |
| f) 140\text{Ba} & \rightarrow & _-1^0\text{e} & +140\text{La} |

7. Write equations for:
   a) The alpha (α) decay of radon- 198 \text{Rn} \rightarrow _2^4\text{He} & +194\text{Po} |
   b) The beta (β) decay of uranium-237 \text{U} \rightarrow _-1^0\text{e} & +237\text{Np} |
   c) Plutonium- 244 undergoes gamma decay \text{Pu}^* & \rightarrow & _0^0\text{Y} & + & 244\text{Pu} |

9. Does the identity of an atom change during radioactive decay? Why or why not?
For alpha and beta decay it does because the proton number changes. During gamma, there is no change of identity, just energy.

10. How does the "Law of Conservation of Matter" explain how you write nuclear equations?
The Law of Conservation of Matter states that matter cannot be created or destroyed. This is why the mass numbers and atomic numbers of the products must add up to equal the mass number and atomic number of the parent isotope.

11. List the 3 types of radiation (α, β, γ) in order from least penetrating to most penetrating.
Alpha = least, Beta = middle, Gamma = most

12. Why would you expect alpha particles to be less able to penetrate materials than beta?
The alpha particle is the largest of the three decay particles, so it will not be able to pass through materials as easily.
13. Why are alpha particles and beta particles deflected in opposite directions in an electric field? Why are gamma rays not deflected?

Both alpha and beta particles are charged. Alpha particles have a positive charge (they contain protons, but not electrons) and beta particles have a negative charge. Since their charges are opposite, they will deflect in opposite directions.

Gamma rays are not deflected because they are neutral.
1. Proton \( \text{C} \)
- Particles with no charge found in the nucleus of atoms.
- Center of the atom; contains protons and neutrons.

2. Neutron \( \text{A} \)
- Positively charged particle in the nucleus of the atom. Determines the element.
- The smallest part of an element or molecule. Building block of all things.

3. Electron \( \text{E} \)
- Negative particles in orbits around the atom.

4. Nucleus \( \text{B} \)
- Smallest part of an element. Can only be split by nuclear means.
- Any combination of two or more elements.

5. Atom \( \text{D} \)
- A substance in which all the atoms are the same.
- Any combination of two or more atoms, whether the same or different.

1. Molecule \( \text{C} \)
- Smallest part of an element. Can only be split by nuclear means.
- Any combination of two or more elements.

2. Compound \( \text{B} \)
- Any combination of two or more molecules, whether the same or different.

3. Atom \( \text{A} \)
- Any combination of two or more elements.

4. Element \( \text{D} \)
- A substance in which all the atoms are the same.

Draw a picture of an atom, using the Bohr model. Be sure to label the nucleus, protons, neutrons, electrons, and orbitals.

Name the subatomic particles that make up the atom.
- Protons: __________
- Neutrons: __________
- Electrons: __________

The number of protons tells you the __________.
The number of electrons tells you the __________.
The number of neutrons tells you the __________.

How did the Rutherford experiment prove the existence of the nucleus?
- Shit alpha particles at gold foil.
- Most particles went thru (empty space).
- When bounced back towards the nucleus,

Find the atomic number of:
- Fe: __________
- K: __________
- Ni: __________
- Al: __________

Find the elements:
- 8 protons: __________
- 6 protons: __________
- 15 protons: __________
- 86 protons: __________

Give the charges for the following:
- 1 electron (e): __________
- 2 electrons (2 e): __________
- 1 proton (p): __________
- 4 protons (4 p): __________
- 1 neutron (n): __________
- 3 neutrons (3 n): __________

\[ \begin{align*}
\text{3}^\text{p} + 3^\text{p} + 2^\text{e} = \text{+1} \\
6^\text{p} + 7^\text{n} + 8^\text{e} = \text{-2} \\
9^\text{p} + 10^\text{n} + 10^\text{e} = \text{-1}
\end{align*} \]
1. Isotope \( D \)  

2. Atomic mass \( A \)  

3. Atomic \# \( F \)  

4. Neutral atom \( B \)  

5. Ion \( C \)  

6. Mass \# \( E \)  

Give abbreviations and number of protons  

<table>
<thead>
<tr>
<th>Element</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Abbreviation</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
</tr>
</thead>
<tbody>
<tr>
<td>Calcium (Ca)</td>
<td>20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>19</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Selenium (Se)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Copper (Cu)</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Silver (Ag)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Zirconium (Zr)</td>
<td>40</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Which of the following are isotopes? 

Element A: \( 15 \) protons; \( 15 \) electrons; \( 15 \) neutrons  
Element B: \( 14 \) protons; \( 16 \) electrons; \( 11 \) neutrons  
Element C: \( 15 \) protons; \( 18 \) electrons; \( 15 \) neutrons  
Element D: \( 16 \) protons; \( 18 \) electrons; \( 15 \) neutrons  
Element E: \( 15 \) protons; \( 18 \) electrons; \( 4 \) neutrons  

Give the element abbreviation and charge.  

<table>
<thead>
<tr>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Abbreviation</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>2</td>
<td></td>
<td>( \text{H}^+ )</td>
<td>+1</td>
</tr>
<tr>
<td>16</td>
<td>18</td>
<td></td>
<td>( \text{N}^- )</td>
<td>-3</td>
</tr>
<tr>
<td>35</td>
<td>36</td>
<td></td>
<td>( \text{Cl}^- )</td>
<td>-1</td>
</tr>
<tr>
<td>12</td>
<td>10</td>
<td></td>
<td>( \text{Mg}^{2+} )</td>
<td>+2</td>
</tr>
</tbody>
</table>

What's wrong with this picture of an atom?  

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>1</td>
<td></td>
<td>+1</td>
</tr>
</tbody>
</table>

This picture is supposed to be of a neutral atom. Fix it.  

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>1</td>
<td></td>
<td>+1</td>
</tr>
</tbody>
</table>

What's wrong with this picture of an atom?  

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>1</td>
<td></td>
<td>+1</td>
</tr>
</tbody>
</table>

What's wrong with this picture of an atom?  

<table>
<thead>
<tr>
<th>Atoms</th>
<th>Protons</th>
<th>Electrons</th>
<th>Neutrons</th>
<th>Charge</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>9</td>
<td>1</td>
<td></td>
<td>+1</td>
</tr>
</tbody>
</table>

Which row is Lithium (Li) in? \( 2 \). It has electrons in levels 1 and 2.  

Which row is phosphorous (P) in? \( 3 \). So, phosphorous has electrons in which electron levels? \( 1, 2, 3 \).  

Which row is calcium (Ca) in? \( 4 \). So, calcium has electrons in what levels? \( 1, 2, 3, 4 \).  

Which row is argon (Ar) in? \( 3 \). So, argon has electrons in what levels? \( 1, 2, 3 \).  

Argon (Ar) is at the end of row \( 3 \). So argon has \( 3 \) full electron levels.  

Helium (He) is at the end of row \( 1 \). So helium has \( 1 \) full electron levels.  

Xenon (Xe) is at the end of row \( 5 \). So xenon has \( 5 \) full electron levels.  

How many full electron levels does Calcium have? \( 3 \).  

How many full electron levels does Sulfur have? \( 2 \).
1. Octet Rule: A. Elements found on the right side of the periodic table.
   B. Elements found on the left side of the periodic table.


3. Valence electrons: C. Says that atoms tend to be more stable with eight valence electrons.

4. Non-metals: A. Metal or Non-metal?

   - M. Aluminum (Al)
   - N. Oxygen (O)
   - H. Gold (Au)
   - V. Nitrogen (N)
   - V. Bromine (Br)
   - V. Krypton (Kr)

   7 protons and 10 electrons. Neutral atom or ion? Incorrect
   15 protons and 15 electrons. Neutral atom or ion? Incorrect
   35 protons and 37 electrons. Neutral atom or ion? Incorrect

   Give the element abbreviation and charge.
   5 protons and 2 electrons: Element B: Charge: +3
   16 protons and 18 electrons: Element: Charge: -2
   35 protons and 36 electrons: Element: Charge: -1

   Element: Na (Sodium)
   # of neutrons: 12
   Mass #: 23 = 11 + 12
   # of electrons: 11
   # of valence electrons: 1
   It is an ion? No - Neutral

   Element: He (2 prot)
   # of neutrons: 2
   Mass #: 4
   # of electrons: 2
   # of valence electrons: 2
   It is an ion? Yes

   Element: Ne (Ne)
   # of neutrons: 10
   Mass #: 20
   # of electrons: 10
   # of valence electrons: 8
   It is an ion? No

   How many valence electrons?
   Calcium (Ca) 2
   Hydrogen (H) 1
   Potassium (K) 1
   Helium (He) 2
   Oxygen (O) 6
   Aluminum (Al) 3
   Argon (Ar) 8
   Sodium (Na) 1
   Boron (B) 3
   Nitrogen (N) 5

   Connect the element on the left with the element on the right that has similar reactivity.
   Chlorine
   Phosphorous
   Magnesium
   Beryllium
   Potassium
   Iodine
   Sodium
   Aluminum
   Boron
   Oxygen
   Sulfur
   Nitrogen

   Elements with the same # of valence electrons have the same reactivity.

   Are these elements isotopes of one another?
   Element A: 12 protons; 11 electrons; 13 neutrons.
   Element B: 13 protons; 12 electrons; 13 neutrons.

   Are these elements isotopes of one another?
   Element A: 14 protons; 15 electrons; 13 neutrons.
   Element B: 14 protons; 15 electrons; 15 neutrons.

   Are these elements isotopes of one another?
   Element A: 12 protons; 11 electrons; 13 neutrons.
   Element B: 12 protons; 12 electrons; 13 neutrons.

   Are these elements isotopes of one another?
   Element A: 18 protons; 18 electrons; 18 neutrons.
   Element B: 18 protons; 18 electrons; 19 neutrons.

   Sulfur (S) is in row 3. Sulfur has 2 complete electron levels and 6 valence electrons in level 3.

   Magnesium (Mg) is in row 3. Magnesium has 2 complete electron levels and 2 valence electrons in level 3.

   Carbon (C) is in row 2. Carbon has 1 complete electron levels and 4 valence electrons in level 2.

   Potassium (K) is in row 4. Potassium has 3 complete electron levels and 1 valence electrons in level 4.

   Argon (Ar) is in row 3. Argon has 2 complete electron levels and 8 valence electrons in level 3.
<table>
<thead>
<tr>
<th>Isotope D</th>
<th>An average of all the isotopes; the mass of average atom.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atomic mass K</td>
<td>An atom with an equal number of electrons and protons.</td>
</tr>
<tr>
<td>Atomic # F</td>
<td>An atom with more or less electrons than protons.</td>
</tr>
<tr>
<td>Neutral atom B</td>
<td>A variation of an element with a different number of neutrons.</td>
</tr>
<tr>
<td>Ion C</td>
<td>Total number of protons and neutrons in the nucleus.</td>
</tr>
<tr>
<td>Mass # E</td>
<td>Number of protons; determines the element.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>How many valence electrons?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Helium (He) 2</td>
</tr>
<tr>
<td>Calcium (Ca) 2</td>
</tr>
<tr>
<td>Sulfur (S) 6</td>
</tr>
<tr>
<td>Calcium and Mg or Be have the same reactivity. Oxygen and <strong>O</strong> have the same reactivity. Helium and Ne have the same reactivity.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Metal or Non-metal?</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Titanium (Ti)</td>
</tr>
<tr>
<td>Sodium (Na)</td>
</tr>
<tr>
<td>Chlorine (Cl)</td>
</tr>
<tr>
<td>8 protons and 10 electrons.</td>
</tr>
<tr>
<td>16 protons and 18 electrons.</td>
</tr>
<tr>
<td>20 protons and electrons.</td>
</tr>
</tbody>
</table>

Give the element abbreviation and charge.
16 protons and 18 electrons: Element: 2- Charge: 2-
35 protons and 36 electrons: Element: 3- Charge: 3-

A 35 N object feels like 30 N when lowered into a liquid. How much buoyant force does the liquid give? 5 N up.

If put into a more viscous liquid, the object would feel even lighter.

"Atoms are solid." Respond and give reasons for your response. No—made up of mostly empty space. Coil foil experiment.

<table>
<thead>
<tr>
<th><strong>Are these different elements?</strong> YES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element A: 17 protons; 18 electrons; 16 neutrons.</td>
</tr>
<tr>
<td>Element B: 18 protons; 18 electrons; 18 neutrons.</td>
</tr>
<tr>
<td>Why? Different prot.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Are these different isotopes of one another?</strong> YES</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element A: 12 protons; 11 electrons; 13 neutrons.</td>
</tr>
<tr>
<td>Element B: 12 protons; 12 electrons; 14 neutrons.</td>
</tr>
<tr>
<td>Why? Same prot, different neut.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Are these different isotopes of one another?</strong> NO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Element A: 18 protons; 18 electrons; 18 neutrons.</td>
</tr>
<tr>
<td>Element B: 19 protons; 18 electrons; 19 neutrons.</td>
</tr>
<tr>
<td>Why? Different elem.</td>
</tr>
</tbody>
</table>

Calcium (Ca) is in row 4. Calcium has 3 complete electron levels and 2 valence electrons in level 4.

Sulfur (S) is in row 3. Sulfur has 2 complete electron levels and 6 valence electrons in level 3.
1. Physical change (F) 2. Chemical reaction (C) 3. Endothermic (D) 4. Exothermic (A) 5. Reactants (B) 6. Products (E)

<table>
<thead>
<tr>
<th>Evidence of a Chemical or Physical Change?</th>
<th>Evidence of a Chemical or Physical Change?</th>
</tr>
</thead>
<tbody>
<tr>
<td>C: Bubbles are formed.</td>
<td>f: Chewing food into smaller pieces.</td>
</tr>
<tr>
<td>P: Melting wax</td>
<td>&lt;: When acids in your stomach break down your food into nutrients your body can absorb.</td>
</tr>
<tr>
<td>C: Gets cold endothermic</td>
<td>c: When enzymes in your saliva pre-digest and soften your food in your mouth before you swallow.</td>
</tr>
<tr>
<td>C: Color changes</td>
<td>p: Boiling water</td>
</tr>
<tr>
<td>C: Changes smell</td>
<td>A: Precipitate</td>
</tr>
<tr>
<td>P: Breaking glass</td>
<td>A: A safer way to smell chemicals.</td>
</tr>
<tr>
<td></td>
<td>B: Tells you the number of molecules.</td>
</tr>
</tbody>
</table>

What two sets of household chemical must you NEVER mix together? Be sure to give what they create.

 Chlorine Bleach + Vinegar = Mustard gas
 Ammonia + Cl bleach = Cl gas

Why are smelling or tasting chemicals dangerous?

Could be harmful

If you HAD to smell a chemical, how would you do it?

Waft it: wave some toward you.

Endothermic or Exothermic Reaction?

- An activated heat pack?
- Two chemicals are mixed and get hot?
- Two chemicals are mixed and get cold?
- Heat goes into the reaction?
- An activated cold pack?
- Heat comes out of a reaction?

Is dissolving salt into water a physical or chemical change? (Be sure to give proof one way or the other.)

Physical: still salt (taste it)
Boil off water + get salt back.

How many total molecules are there?

<table>
<thead>
<tr>
<th>Li₂O + MgCl₂ → 2LiCl + MgO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Name the second reactant:</td>
</tr>
<tr>
<td>Name the first product:</td>
</tr>
<tr>
<td>How many Lithiums on the product side?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>2AlCl₃ + 3Na₂CO₃ → Al₄(CO₃)₃ + 6NaCl</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle the first reactant.</td>
</tr>
<tr>
<td>Underline the second reactant.</td>
</tr>
<tr>
<td>How many Sodium atoms on the reactant side?</td>
</tr>
<tr>
<td>How many table salt molecules on the product side?</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Fe₂O₃ + 3C → 2Fe + 3CO</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circle and Name the second product:</td>
</tr>
<tr>
<td>How many total atoms on the reactant side:</td>
</tr>
<tr>
<td>How many total molecules on the product side:</td>
</tr>
</tbody>
</table>
The Greek philosopher Democritus believed there to be a smallest, indivisible particle: atoms. In the early 20th century scientists learned that the atom is indeed divisible (can be split) and even fusible (can be combined).

Neutrons add strong nuclear force without repelling the protons. That is why as atoms add more protons, they have to add more neutrons (like glue) to keep the nucleus together. But eventually the strong nuclear force is not strong enough.

The strong nuclear force is a short distance force. The electro-magnetic repulsion of the protons is a long distance force. Eventually there are too many protons and the repulsion of the protons wins. Over 83 protons and the nucleus will undergo radioactive decay.

There are three kinds of radiation: alpha decay; beta decay; gamma rays.

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
<th>Atomic Changes</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alpha Decay</td>
<td>Low energy particle. Helium nucleus: 2 protons; 2 neutrons; stopped by paper or skin</td>
<td>Mass number: -4 (2p + 2n)</td>
<td>U-238 → Th-234 + α (Alpha particle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Atomic number: -2 (protons)</td>
<td></td>
</tr>
<tr>
<td>Beta Decay</td>
<td>A Neutron splits into a proton and an electron. Stopped by clothes or wood.</td>
<td>Mass number: no change</td>
<td>C-14 → N-14 + β (Beta particle)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Atomic number: +1</td>
<td></td>
</tr>
<tr>
<td>Gamma Radiation</td>
<td>High energy radiation. Stopped by lead or many feet of concrete. Dangerous to living things.</td>
<td>No changes</td>
<td>No changes γ (Gamma ray)</td>
</tr>
</tbody>
</table>

If Fluorine 20 undergoes beta decay, what will it become?

\[
\begin{align*}
^{19}\text{F} & \rightarrow \text{β} + ^{19}\text{Ne}
\end{align*}
\]

If Sulfur 34 undergoes alpha decay, what will it become?

\[
\begin{align*}
^{34}\text{S} & \rightarrow ^4\text{He} + ^{30}\text{Si}
\end{align*}
\]

This is the decay series for Uranium-238. (Atomic numbers are on the bottom.) On each arrow put either a “α” for alpha decay or “β” for beta decay.

\[
\begin{align*}
^{238}\text{U} & \rightarrow ^{234}\text{Th} \rightarrow ^{234}\text{Pa} \rightarrow ^{234}\text{U} \rightarrow ^{230}\text{Th} \\
^{226}\text{Ra} & \rightarrow ^{222}\text{Rn} \rightarrow ^{218}\text{Po} \rightarrow ^{214}\text{Pb} \rightarrow ^{214}\text{Bi} \\
^{214}\text{Po} & \rightarrow ^{210}\text{Pb} \rightarrow ^{210}\text{Bi} \rightarrow ^{210}\text{Po} \rightarrow ^{206}\text{Pb}
\end{align*}
\]
Fission versus Fusion

Nuclear plants use fission.

There are two types of nuclear reactions.

The sun uses fusion and is the source of all power on earth.

Fission

Uranium is split into smaller atoms.

1 lb completely fissioned Uranium = 6,000 barrels of oil = 1,000 tons high-quality coal

Nuclear Process

Energy Produced

Waste Products

Fusion

Small atoms are fused together. Two hydrogen atoms are fused into a helium atom.

1 km³ of sea water = more energy than all known fossil fuels in the world.

Perfectly safe Helium. We could make balloons.

Toxic radioactive waste that takes billions of years of decay to become safe.

The real winner: nuclear fusion. So why don’t we use it? Fusion occurs in the sun. It takes millions of degrees to even start fusion. So far we can’t control it. But scientists are working on it.

As a future voter — demand money for fusion research!

Half-life

Half-life: the time it takes half of a radioactive substance to decay. Carbon-14 has a half-life of 5,730 years. In 5,730 years 100 kg of carbon-14 would reduce to 50 kg. Unfortunately, a radioactive substance never decays to zero; there’s always a half more.

<table>
<thead>
<tr>
<th>A simple example:</th>
<th>After 50 years:</th>
<th>After 100 years:</th>
<th>After 150 years:</th>
<th>After 200 years:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Half-life: 50 years</td>
<td>(1st half-life) 200 kg left</td>
<td>(2nd half-life) 100 kg left</td>
<td>(3rd half-life) 50 kg left</td>
<td>(4th half-life) 25 kg left</td>
</tr>
</tbody>
</table>

Carbon Dating

Scientists use the known half-life of carbon-14 (5,730 years) to date plants, animals, and artifacts less than 50,000 years old. We know how much carbon-14 is in things when they die, so by analyzing how much carbon-14 is in a sample today, scientists know when something died.

Chain Reactions

In fission a neutron splits a nucleus. This produces another neutron (or more), which splits another nucleus, making more neutrons, etc. A chain reaction is like toppling dominos.

1. Alpha Particle
2. Gamma Ray
3. Beta Particle
4. Radioactive
5. Uranium

A. The largest natural element. Fuel for fission reactors.
B. Can be stopped by wood; occurs when a neutron breaks into a proton and electron.
C. An atom that emits energy or a particle is called this.
D. A helium nucleus (2 protons and 2 neutrons); low in energy.
E. Powerful radiation that can cause biological damage; takes many feet of concrete to stop.

1. Chain Reaction
2. Fission
3. Fusion
4. Half-life
5. Carbon Dating

A. Combining smaller atoms into larger atoms. Harmless products; stars use this.
B. Splitting large atoms into smaller ones. Toxic by-products.
C. When one fission causes another and another, etc.
D. Using the known decay of an isotope to determine the age of objects.
E. The time necessary for 50% of a radioactive sample to decay.
**Enthalpy Diagrams & Thermochemical Equations WS**

**Directions:** Evaluate the following enthalpy diagrams and answer the associated questions.

1) \( \text{H}_2 (g) + \text{I}_2 (g) \rightarrow 2 \text{HI} (aq) \)

1) Is this reaction endothermic or exothermic? Explain why.

\[ \text{EXO} \]
\[ \text{Loss of Energy From R} \rightarrow \text{P} \]

2) \( \text{N}_2 (g) + 2 \text{O}_2 (g) \rightarrow 2 \text{NO}_2 (g) \)

2) Is this reaction endothermic or exothermic? Explain why.

\[ \text{ENDO} \]
\[ \text{Gain of Energy From R} \rightarrow \text{P} \]

3) Are the following reactions endothermic or exothermic?

a. \( 2 \text{C (s)} + \text{H}_2 (g) + 226.6 \text{kJ} \rightarrow \text{C}_2\text{H}_2(\text{g}) \)  **ENDO**

b. \( 2 \text{C}_3\text{H}_6 (g) + 9 \text{O}_2 (g) \rightarrow 6 \text{CO}_2 (g) + 6 \text{H}_2\text{O} (l) + 4439.4 \text{kJ} \)  **EXO**

c. \( 2 \text{C}_2\text{H}_6 (g) + 7 \text{O}_2 (g) \rightarrow 4 \text{CO}_2 (g) + 6 \text{H}_2\text{O} (l) \)  \( \Delta H = -3120 \text{kJ} \)  **EXO**

e. \( 2 \text{Ag}_2\text{O(s)} \rightarrow 4 \text{Ag(s)} + \text{O}_2(\text{g}) \)  \( \Delta H = +122 \text{kJ} \)  **ENDO**

f. \( 2 \text{Na (s)} + \text{Cl}_2 (g) \rightarrow 2 \text{NaCl (s)} \)  \( \Delta H = -822 \text{kJ} \)  **EXO**

g. \( 2 \text{C}_2\text{H}_2 (g) + 5 \text{O}_2 (g) \rightarrow 4 \text{CO}_2 (g) + 2 \text{H}_2\text{O} (l) + 2598.8 \text{kJ} \)  **EXO**

h. \( 4 \text{NO (g)} + 6 \text{H}_2\text{O} (l) +1170 \text{kJ} \rightarrow 4 \text{NH}_3 (g) + 5 \text{O}_2 (g) \)  **ENDO**