PROBLEM \PageIndex{1}

In the following drawing, the green spheres represent atoms of a certain element. The purple spheres represent atoms of another element. If the spheres of different elements touch, they are part of a single unit of a compound. The following chemical change represented by these spheres may violate one of the ideas of Dalton's atomic theory. Which one?

\[
\text{Starting materials } \quad \text{Products of the change}
\]

Answer

The starting materials consist of one green sphere and two purple spheres. The products consist of two green spheres and two purple spheres. This violates Dalton's postulate that atoms are not created during a chemical change, but are merely redistributed.

PROBLEM \PageIndex{2}

Which postulate of Dalton's theory is consistent with the following observation concerning the weights of reactants and products?

When 100 grams of solid calcium carbonate is heated, 44 g of CO\textsubscript{2} and 56 g of CaO are produced.

Answer

Atoms are neither created nor destroyed during a chemical change, but are instead rearranged to yield substances that are different from those present before the change (Based on the Law of Conservation of Mass).

PROBLEM \PageIndex{3}

Samples of compound X, Y, and Z are analyzed, with results shown here. Do these data provide example(s) of the law of definite proportions, the law of multiple proportions, neither, or both? What do these data tell you about compounds X, Y, and Z?

<table>
<thead>
<tr>
<th>Compound</th>
<th>Description</th>
<th>Mass of Carbon</th>
<th>Mass of Hydrogen</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>clear, colorless, liquid with strong odor</td>
<td>1.776 g</td>
<td>0.148 g</td>
</tr>
<tr>
<td>Y</td>
<td>clear, colorless, liquid with strong odor</td>
<td>1.974 g</td>
<td>0.329 g</td>
</tr>
<tr>
<td>Z</td>
<td>clear, colorless, liquid with strong odor</td>
<td>7.812 g</td>
<td>0.651 g</td>
</tr>
</tbody>
</table>

Answer

X+Z are similar compounds (same ratios of C and H), aligning with the Law of Definite Proportions

X+Y and Y+Z are different compounds (differing ratios of C and H), aligning with the Law of Multiple Proportions
Click here to see a video of the solution.

Media, iframe, embed and object tags are not supported inside of a PDF.

PROBLEM \(\PageIndex{4}\))

How are electrons and protons similar? How are they different?

Answer

Electrons and protons are both charged subatomic particles.

Protons are much larger than electrons (contributing more mass to the overall atom).

Changing the number of protons changes the identity of the atom, which changing the number of electrons changes the charge.

PROBLEM \(\PageIndex{5}\))

How are protons and neutrons similar? How are they different?

Answer

Protons and neutrons are both located in the nucleus of the atom.

Protons and neutrons both contribute to the overall mass of the atom.

Protons carry a charge while neutrons are neutral.

PROBLEM \(\PageIndex{6}\))
Predict and test the behavior of α particles fired at a “plum pudding” model atom.

(a) Predict the paths taken by α particles that are fired at atoms with a Thomson’s plum pudding model structure. Explain why you expect the α particles to take these paths.

(b) If α particles of higher energy than those in (a) are fired at plum pudding atoms, predict how their paths will differ from the lower-energy α particle paths. Explain your reasoning.

(c) Now test your predictions from (a) and (b).

Select the “Plum Pudding Atom” tab above. Set “Alpha Particles Energy” to “min,” and select “show traces.” Click on the gun to start firing α particles. Does this match your prediction from (a)? If not, explain why the actual path would be that shown in the simulation. Hit the pause button, or “Reset All.” Set “Alpha Particles Energy” to “max,” and start firing α particles. Does this match your prediction from (b)? If not, explain the effect of increased energy on the actual paths as shown in the simulation.

Answer a

The plum pudding model indicates that the positive charge is spread uniformly throughout the atom, so we expect the α particles to (perhaps) be slowed somewhat by the positive-positive repulsion, but to follow straight-line paths (i.e., not to be deflected) as they pass through the atoms.

Answer b

Higher-energy α particles will be traveling faster (and perhaps slowed less) and will also follow straight-line paths through the atoms.

Answer c

The α particles followed straight-line paths through the plum pudding atom. There was no apparent slowing of the α particles as they passed through the atoms.

PROBLEM \(\PageIndex{7}\)

Predict and test the behavior of α particles fired at a Rutherford atom model.

(a) Predict the paths taken by α particles that are fired at atoms with a Rutherford atom model structure. Explain why you expect the α particles to take these paths.

(b) If α particles of higher energy than those in (a) are fired at Rutherford atoms, predict how their paths will differ from the lower-energy α particle paths. Explain your reasoning.
(c) Predict how the paths taken by the α particles will differ if they are fired at Rutherford atoms of elements other than gold. What factor do you expect to cause this difference in paths, and why?

(d) Now test your predictions from (a), (b), and (c).

Select the “Rutherford Atom” tab above. Due to the scale of the simulation, it is best to start with a small nucleus, so select “20” for both protons and neutrons, “min” for energy, show traces, and then start firing α particles. Does this match your prediction from (a)? If not, explain why the actual path would be that shown in the simulation. Pause or reset, set energy to “max,” and start firing α particles. Does this match your prediction from (b)? If not, explain the effect of increased energy on the actual path as shown in the simulation. Pause or reset, select “40” for both protons and neutrons, “min” for energy, show traces, and fire away. Does this match your prediction from (c)? If not, explain why the actual path would be that shown in the simulation. Repeat this with larger numbers of protons and neutrons. What generalization can you make regarding the type of atom and effect on the path of α particles? Be clear and specific.

Answer a

The Rutherford atom has a small, positively charged nucleus, so most α particles will pass through empty space far from the nucleus and be undeflected. Those α particles that pass near the nucleus will be deflected from their paths due to positive-positive repulsion. The more directly toward the nucleus the α particles are headed, the larger the deflection angle will be.

Answer b

Higher-energy α particles that pass near the nucleus will still undergo deflection, but the faster they travel, the less the expected angle of deflection.

Answer c

If the nucleus is smaller, the positive charge is smaller and the expected deflections are smaller—both in terms of how closely the α particles pass by the nucleus undeflected and the angle of deflection. If the nucleus is larger, the positive charge is larger and the expected deflections are larger—more α particles will be deflected, and the deflection angles will be larger.

Answer d

The paths followed by the α particles match the predictions from (a), (b), and (c).
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