
Welcome!
This is a chemistry lesson, covering *isotopes*.
I will guide you step-by-step.

I will be asking you many questions along the way.

Each time I ask a question, **you should attempt to answer the question on your own**
before you scroll down to view my answer.

This is a lesson in the chapter “Atoms, Molecules, and Compounds”,
which is the first chapter of the course, “Chemistry, Explained Step by Step”.

This lesson builds on the material we covered in the previous lessons:
Atoms, Protons, Neutrons, and Electrons
Atomic Number and Mass Number

You should complete those lessons before working through this one.

This lesson was written by Freelance-Teacher.

My website is:
www.freelance-teacher.com

You can support this project with a monthly pledge at my Patreon page:
www.patreon.com/freelanceteacher

Or you can make a one-time donation using the PayPal Donate link at my website.

I have videos available for many topics in chemistry, and other subjects, at my YouTube channel:
www.youtube.com/@freelanceteach

You can find a list of all the available lessons, in suggested order, at my website.
You can find AI-enhanced versions of all the lessons, which allow you to ask questions, and which can generate additional practice problems, at my website.
You can find a list of all the available videos, in suggested order, at my website.

I offer **tutoring** in chemistry, and a variety of other subjects.
For more information, go to my website.

In the previous lessons, we have learned that, for example, all hydrogen atoms have the same number of protons,
but different hydrogen atoms can have different numbers of neutrons.

Two atoms that have the same number of protons but different numbers of neutrons are called *isotopes* of each other.

For example, if two hydrogen atoms have different numbers of neutrons,
those two atoms are called *isotopes* of each other.

To be more specific, if one hydrogen atom has 1 proton and zero neutrons,
and another hydrogen atom has 1 proton and 1 neutron,
then those two hydrogen atoms are called isotopes of each other.

For another example, if two sulfur atoms have different numbers of neutrons,
then those two atoms are called isotopes of each other.

To be more specific, if one sulfur atom has 16 protons and 16 neutrons,
and another sulfur atom has 16 protons and 17 neutrons,
and another sulfur atom has 16 protons and 18 neutrons,
and another sulfur atom has 16 protons and 20 neutrons,
then those four types of sulfur atoms would represent four different isotopes of sulfur.

---

1. What is the definition of isotopes?

Isotopes are atoms
with the *same* number of protons, and
different numbers of neutrons.

---

2. A particular atom has 15 neutrons and 15 protons.
Another atom has 16 neutrons and 15 protons.
Are these two atoms isotopes of each other?

Answer:
Yes, these two particular atoms are isotopes of each other
(they are both isotopes of phosphorus).

Analysis:
Isotopes are atoms
with the same number of *protons*, and
different numbers of *neutrons*.

Both atoms have
the same number of protons (15), and
different numbers of neutrons (15 and 16).

This matches the definition of isotopes.
So *yes*, these two particular atoms are isotopes of each other.

Because they each have 15 protons,
we know from the periodic table that they are both isotopes of phosphorus.

---

3. A particular atom has 6 neutrons and 7 protons.
Another atom has 6 neutrons and 8 protons.
Are these two atoms isotopes of each other?

Answer:
No, these two particular atoms are *not* isotopes of each other.
They represent completely different elements (nitrogen and oxygen).

Analysis:
Isotopes are atoms
with the same number of *protons*, and
different numbers of *neutrons*.

The two atoms have
different numbers of protons (7 and 8), and
the same number of neutrons (6).

This does not match the definition of an isotope.
So *no*, these two particular atoms are *not* isotopes.

From the periodic table, we know that
the atom with 7 protons represents the element nitrogen,
and the atom with 8 protons represents the element oxygen;
so these two atoms represent two completely different elements.

---

4. Atom A has 8 neutrons and 6 protons.
Atom B has 8 neutrons and 7 protons.
Atom C has 9 neutrons and 6 protons.
Atom D has 8 neutrons and 6 protons.

What is the relationship between atom A and atom B?
(isotopes, different elements, or the same exact type of atom?)

What is the relationship between atom A and atom C?
What is the relationship between atom A and atom D?
What is the relationship between atom B and atom C?
What is the relationship between atom B and atom D?
What is the relationship between atom C and atom D?

Answer:
A and B are different elements.
A and C are isotopes.
A and D are the same exact type of atom.
B and C are different elements.
B and D are different elements.
C and D are isotopes.

Analysis:
A and B have different numbers of protons,
so A and B are different elements (carbon and nitrogen).

A and C have the same number of protons, but different numbers of neutrons,
so A and C are isotopes.
(They are isotopes of carbon.)

A and D have the same number of protons, and the same number of neutrons,
so A and D are the same exact type of atom.
(They are the exact same type of carbon atom.)

B and C have different numbers of protons,
so B and C are different elements (nitrogen and carbon).

B and D have different numbers of protons,
so B and D are different elements (nitrogen and carbon).

C and D have the same number of protons, but different numbers of neutrons,
so C and D are isotopes.
(They are isotopes of carbon.)

---

5. What are isotopes?

Isotopes are atoms with
the same number of protons
but different numbers of neutrons.

There are three naturally occurring isotopes of silicon.

$^{28}_{14}Si$ is an isotope that contains
14 protons and 14 neutrons.
The name of this isotope is “silicon-28”.

$^{29}_{14}Si$ is an isotope that contains
14 protons and 15 neutrons.
The name of this isotope is “silicon-29”.

$^{30}_{14}Si$ is an isotope that contains
14 protons and 16 neutrons.
The name of this isotope is “silicon-30”.

You can see from these examples that
the name for each isotope is based on
the *mass number* for that isotope.

Remember, we learned in the previous lesson that
mass number = number of protons + number of neutrons

$^{28}_{14}Si$ has a mass number of 28,
so its name is “silicon-28”.

$^{29}_{14}Si$ has a mass number of 29,
so its name is “silicon-29”.

$^{30}_{14}Si$ has a mass number of 30,
so its name is “silicon-30”.

If you don’t know how to interpret symbols like $^{28}_{14}Si$,
you should review the previous lesson on Atomic number and mass number.

---

6. Naturally occurring chlorine is a mixture of two isotopes, $^{35}_{17}Cl$ and $^{37}_{17}Cl$.
Figure out as much as you can about each of these two isotopes, including their names.

Answer:
$^{35}_{17}Cl$ contains
17 protons, and
18 neutrons.
The name of this isotope is chlorine-35.

$^{37}_{17}Cl$ contains
17 protons, and
20 neutrons.
The name of this isotope is chlorine-37.

Remember, the name of the isotope is based on the mass number.

If you don't understand how we figured out the numbers of protons and neutrons from the symbols, you should review the lesson on Atomic number and mass number.

---

7. Naturally occurring magnesium is a mixture of three isotopes: magnesium-24, magnesium-25, and magnesium-26.

Figure out as much as you can about each of these three isotopes, including the symbol for each isotope.

Answer:

From its name, we know that magnesium-24 has a mass number of 24.

From the periodic table, we know that magnesium-24 has an atomic number of 12.

From this information, using the techniques we learned about in the previous lesson, we can figure out the following information for magnesium-24:
number of protons = 12
number of neutrons = 12
symbol: $^{24}_{12}Mg$

Similarly, we can figure out the following information for magnesium-25:
mass number = 25
atomic number = 12
number of protons = 12
number of neutrons = 13
symbol: $^{25}_{12}Mg$

And we can figure out the following information for magnesium-26:
mass number = 26
atomic number = 12
number of protons = 12
number of neutrons = 14
symbol: $^{26}_{12}Mg$

---

8. True or false?
If two atoms are isotopes of each other, then those two atoms must both represent the same element.

If true, explain why it's true.
If false, explain why it's false.

Answer: True.

Isotopes are atoms that have
the same number of protons, but
different numbers of neutrons.

As we learned in a previous lesson,
the number of protons is the fundamental thing that identifies each element.

So, if two atoms have the same number of protons,
then they must both represent the same element.

So, if two atoms are isotopes,
then they must both represent the same element.

Atoms that are isotopes represent different "versions" of the same element.

For example, carbon-12 and carbon-13 represent two different "versions" of the element carbon.

Magnesium-24, magnesium-25, and magnesium-26 represent three different "versions" of the element magnesium.

Etc.

In many contexts, it is convenient to assume that an atom is neutral
unless otherwise indicated.

(In fact, many textbooks *define* an atom as neutral;
if an atom is charged, many textbooks would call it an “ion”, not an atom.)

In the rest of this lesson,
we will follow common practice and assume that each isotope discussed is neutral,
unless otherwise indicated.

---

9. True or False?
A neutral atom must have the same number of electrons as protons.

If true, explain why it’s true.
If false, rewrite the statement so that it is true.

Answer: True

We have learned in earlier lessons that
each proton has a +1 electric charge, and
each electron has a -1 electric charge.

It should be apparent that,
a negatively charged atom must have more electrons than protons;
a positively charged atom must have fewer electrons than protons; and
a *neutral* atom must have *equal* numbers of electrons and protons.

Remember that we have decided that, in the rest of this lesson,
we will follow common practice and assume that each isotope discussed is neutral,
unless otherwise indicated.

Since we will be assuming that the isotopes we discuss are neutral,
we will also be assuming that for each isotope
the number of electrons = the number of protons.

In later chapters, we will see that
the chemical properties of an element are primarily determined
by the *number of electrons*.

In contrast, the number of *neutrons*
has almost no effect on the chemical properties of an element.

---

10. True or false?
Chlorine-35 and chlorine-37 can be expected to have near identical chemical properties.

If true, explain why it's true.
If false, explain why it's false.

Answer: True

Chlorine-35 and chlorine-37 are isotopes of the same element.

Therefore, chlorine-35 and chlorine-37 will have
the same number of protons, and
different numbers of neutrons.

Since we are assuming both isotopes are composed of neutral atoms,
chlorine-35 and chlorine-37 will also have
the same number of electrons.

We have learned that the chemical properties of an element are primarily determined
by the number of electrons;
in contrast, the number of neutrons has almost no effect on the chemical properties of an element.

Based on this rule,
since chlorine-35 and chlorine-37 have the same number of electrons
we would indeed expect chlorine-35 and chlorine-37 to have near identical chemical properties.

That's the reason that it's appropriate to consider chlorine-35 and chlorine-37 to represent
different versions of the *same* element! (They are both versions of chlorine.)

The same thing can be said for isotopes of any other element.

For example, magnesium-24, magnesium-25, and magnesium-26 are all isotopes of each other;
so magnesium-24, magnesium-25, and magnesium-26 can be expected to have near identical chemical properties.

That’s the reason that is convenient to consider magnesium-24, magnesium-25, and magnesium-26 to represent different versions of the same element! (They are all different versions of magnesium.)

Similarly, nitrogen-14 and nitrogen-15 are both isotopes of each other;
so nitrogen-14 and nitrogen-15 can be expected to have near identical chemical properties.

That’s the reason that it is convenient to consider nitrogen-14 and nitrogen-15 to represent different versions of the same element! (They are both versions of nitrogen.)

Etc.

Naturally occurring elements are usually a *mixture* of different isotopes.

Naturally occurring magnesium is a *mixture* of
78.99% magnesium-24,
10.00% magnesium-25, and
11.01% magnesium-26.

Similarly, naturally occurring chlorine is a mixture of
75.78% chlorine-35, and
24.22% chlorine-37.

Similarly, naturally occurring titanium is a mixture of
8.25% titanium-46,
7.44% titanium-47,
73.72% titanium-48,
5.41% titanium-49, and
5.18% titanium-50.

Etc.

---

11. True or false: It is difficult to separate naturally occurring magnesium into its three component isotopes.

If true, explain why it's true.
If false, explain why it's false.

Answer:
True.

We have learned that naturally occurring magnesium is a mixture of three isotopes.

But we have also learned that isotopes of the same element have near identical chemical properties.

Therefore, the three isotopes of magnesium have near identical chemical properties.

Therefore, if you have a mixture of the three isotopes of magnesium
it will be near impossible to find a chemical reaction
that affects these three isotopes differently.

So, if you have a mixture of the three isotopes
it would be near impossible to find a chemical reaction
that can separate the three isotopes from each other.

The same thing could be said for any other mixture of isotopes.

It is difficult to separate naturally occurring chlorine into its two component isotopes (chlorine-35 and chlorine-37).

It is difficult to separate naturally occurring titanium into its five component isotopes (titanium-46, titanium-47, titanium-48, titanium-49, and titanium-50).

Etc.

(Isotopes cannot be separated by "chemical" techniques,
but there are "physical" techniques that can be used, with difficulty, to separate isotopes.
But that's a topic you probably won't be exploring in your general chemistry course.)

The word *isotope* has slightly different meanings
when it's used in the plural ("isotopes") or in the singular ("isotope").

If I tell you that "substance A and substance B are *isotopes* of each other",
that means that atoms of substance A have the same number of protons as atoms of substance B,
but different numbers of neutrons.

In contrast, if I tell you that "substance D is an *isotope* of a certain element",
that means that substance D consists of atoms of that element
all of whom contain the *same* number of neutrons.

Here's an example of the use of the word "isotopes", in the plural:
Sodium-22 and sodium-23 are *isotopes* of each other,
because atoms of sodium-22 have the same number of protons as atoms of sodium 23 do
(namely, 11 protons),
but atoms of sodium-22 have a different number of neutrons than atoms of sodium-23 do
(namely, atoms of sodium-22 have 11 neutrons, while atoms of sodium-23 have 12 neutrons).

Here's an example of the use of the word "isotope", in the singular:
Sulfur-33 is an *isotope* of sulfur,
because sulfur-33 is composed of atoms of the element sulfur
all of whom contain the *same* number of neutrons (namely, 17 neutrons).

Let’s review the material that we’ve discussed in this lesson.

---

12. What are isotopes?

Isotopes are atoms with the same number of protons but different numbers of neutrons.

---

13. A particular atom has 8 protons and 10 neutrons. Another atom has 9 protons and 10 neutrons. Are these two atoms isotopes of each other?

No, they are *not* isotopes of each other.

They have different numbers of protons, so they are different elements (oxygen and fluorine),

---

14. A particular atom has 18 protons and 26 neutrons. Another atom has 18 protons and 27 neutrons. Are these two atoms isotopes of each other?

Yes, they are different isotopes of the element argon.

You can see that they are isotopes of each other because they have
the same number of protons, but different numbers of neutrons.

---

15. Tell me as much as possible about oxygen-17.

Answer:
Oxygen-17 is an isotope of the element oxygen.
Each atom of oxygen-17 contains 8 protons and 9 neutrons.
Each atom of oxygen-17 has an atomic number of 8 and a mass number of 17.

(If we make the assumption that we are considering neutral atoms of oxygen-17,
then we also know that each atom has 8 electrons.)

---

16. True or false? If false, how would you rewrite the statement so that it is true?
Naturally occurring elements are usually a mixture of different isotopes.

True.

---

17. True or false? If false, how would you rewrite the statement so that it is true?
We can expect nitrogen-15 to have substantially different chemical properties than nitrogen-14.

Answer:
False.
We can expect nitrogen-15 to have *near identical* chemical properties to nitrogen-14.

Analysis:
Nitrogen-15 and nitrogen-14 are both isotopes of nitrogen.
Different isotopes of the same element usually have *near identical* chemical properties.
That's why nitrogen-15 and nitrogen-14 can be thought of as different "versions" of the element nitrogen.

The reason for this is that the chemical properties of an element are determined by the number of electrons.
(In contrast, the number of neutrons has almost no effect on the chemical properties of an element.)
Different isotopes of the same element have the same number of electrons,
so they have near identical chemical properties.

(We are assuming that the question is referring to *neutral* nitrogen-15 and neutral nitrogen-14.
Neutral isotopes of the same element have the same number of electrons as each other.)

---

18. Substance E is an isotope of phosphorus.
What does that tell you about substance E?

Answer:
Substance E consists of atoms of phosphorus,
each of which contains the same number of neutrons.

From the information given,
we can’t tell how many neutrons each atom of substance E contains;
but we do know that each atom of substance E contains 15 protons.

You have reached the end of this lesson.

The next lesson is not yet available, but I hope to post it shortly.

When it’s available, you will be able to find the next lesson on my website:
www.freelance-teacher.com