General Chemistry

(CHE 101)

Summer 2020

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Topics Breakdown

Part I

- Chemistry: The Study of Change (Chapter 1)
- Atoms, Molecules and Ions (Chapter 2)
- Quantum Theory and the Electronic Structure of Atoms (Chapter 7)

&

- Periodic Relationships Among the Elements (Chapter 8)

Topics Breakdown

Part I

- Chemistry: The Study of Change (Q -1)
- Atoms, Molecules and Ions (Q -1)
- Quantum Theory and the Electronic Structure of Atoms (Q -2)

&

- Periodic Relationships Among the Elements (Q -2)

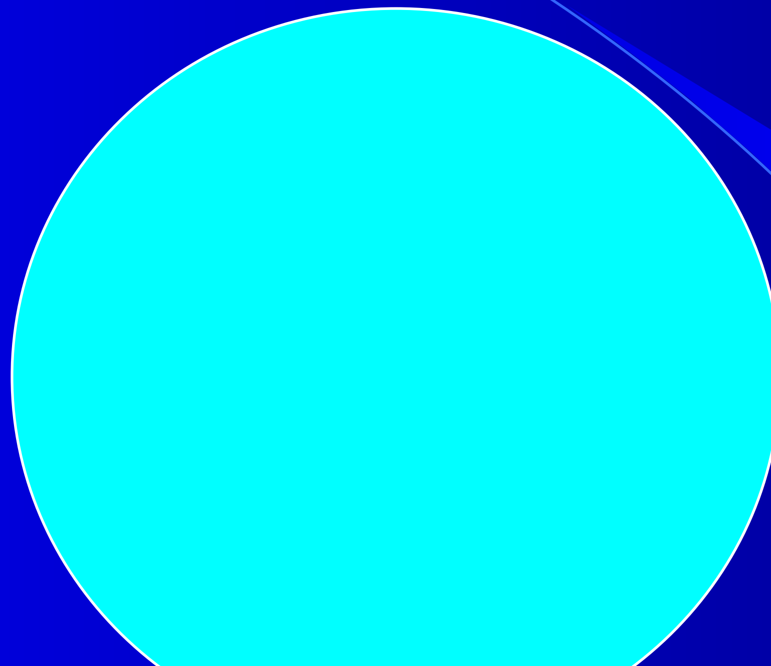
Chapter 1

Chemistry : The study of change

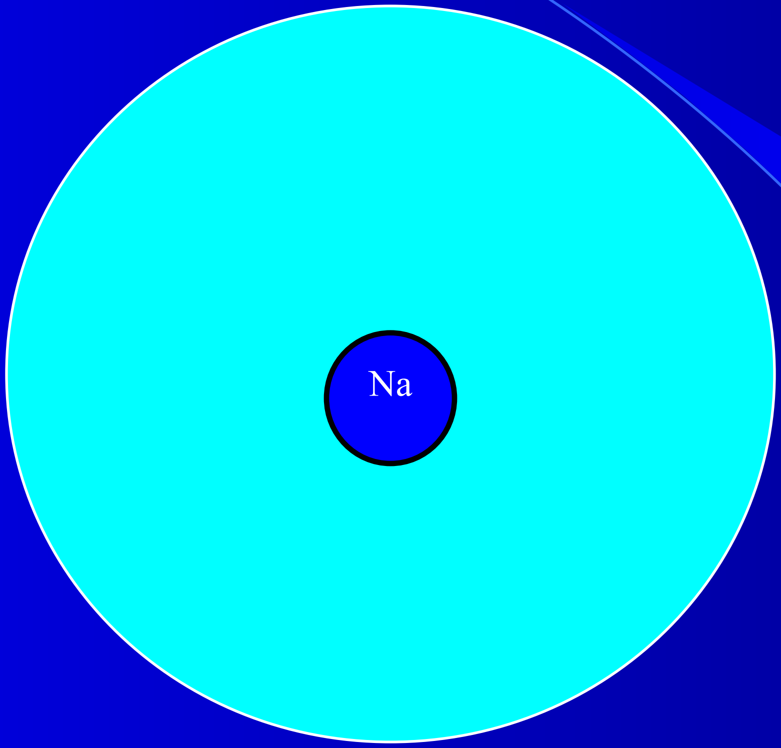
Chemistry...?

…is a subdivision of physical science that focuses on what happens when the **electron cloud** of one substance encounters the **electron cloud** of another

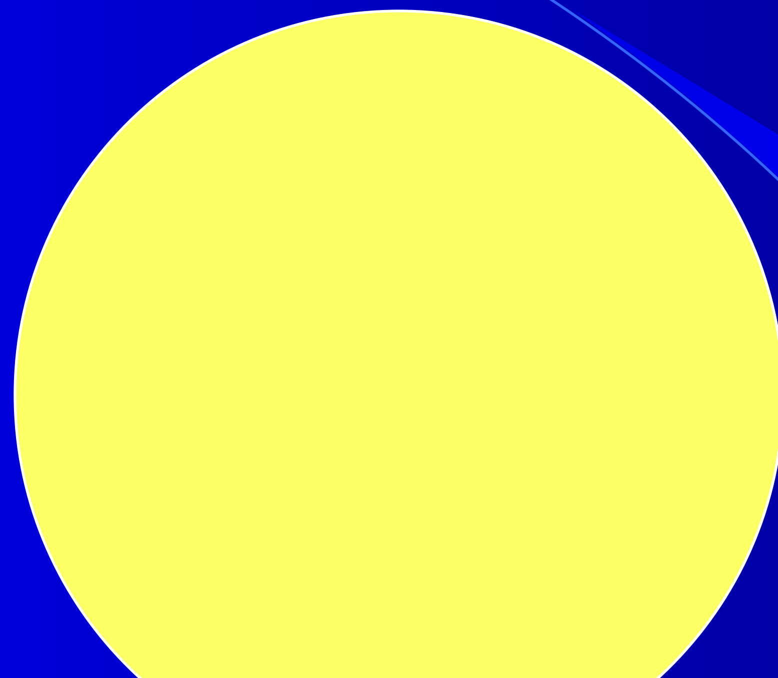
An atom



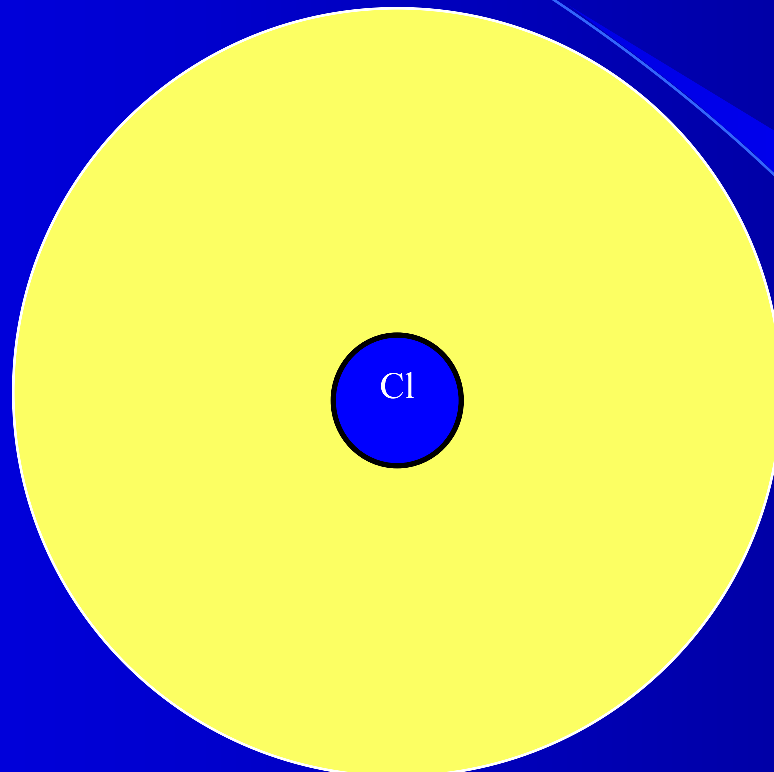
A Sodium atom - Na



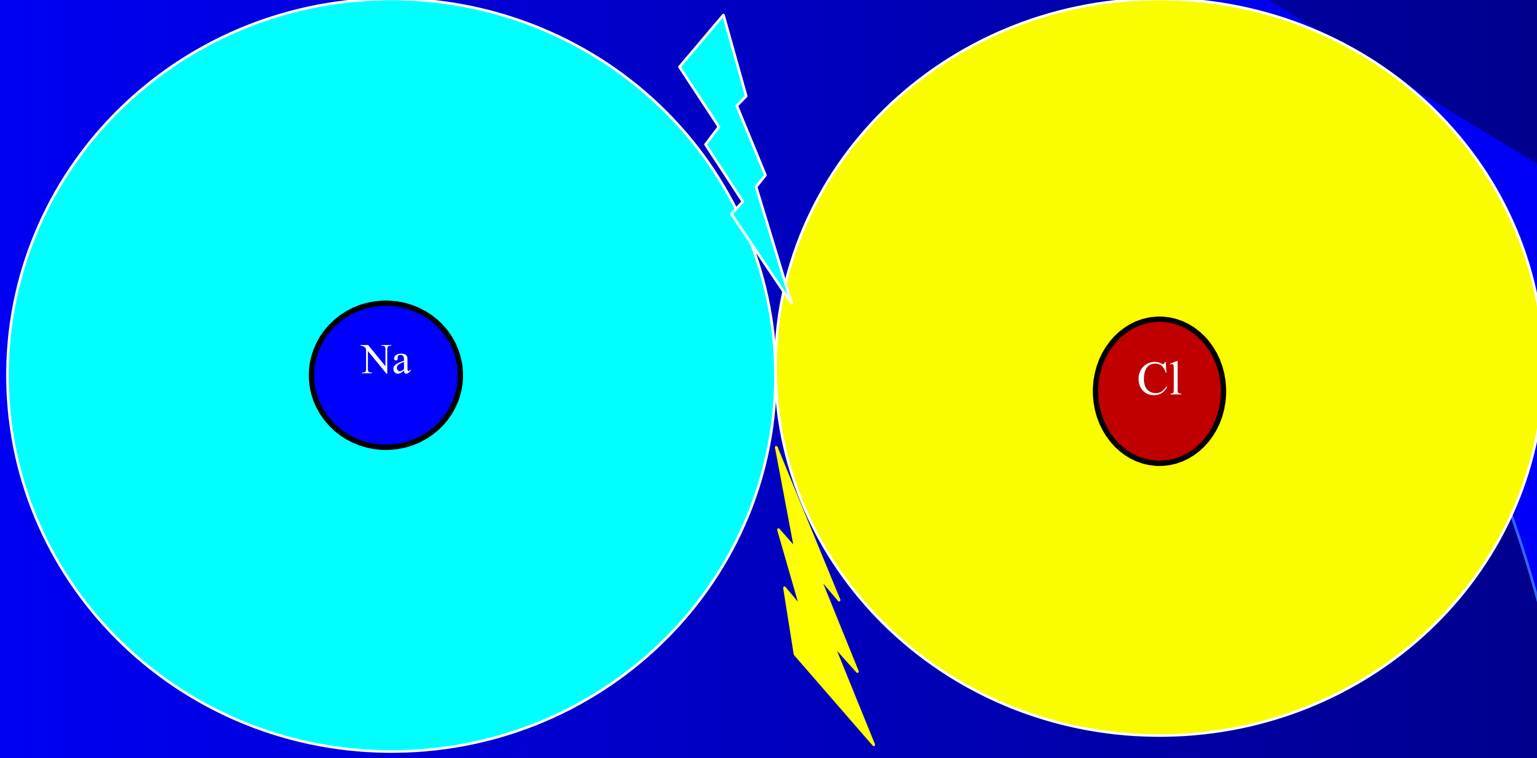
Another atom



A Chlorine atom - Cl

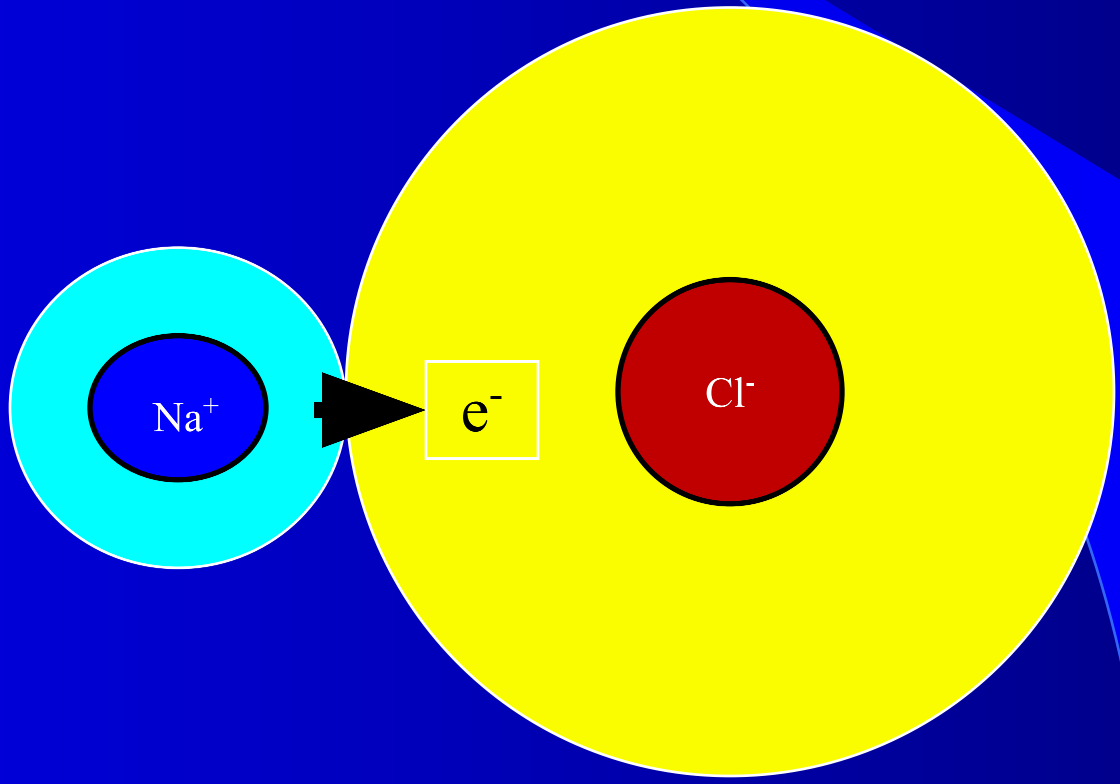


When they collide…i.e., when two atoms collide…



When two atoms collide…

Electrons may be transferred
(ionization occurs!)



When two atoms collide…

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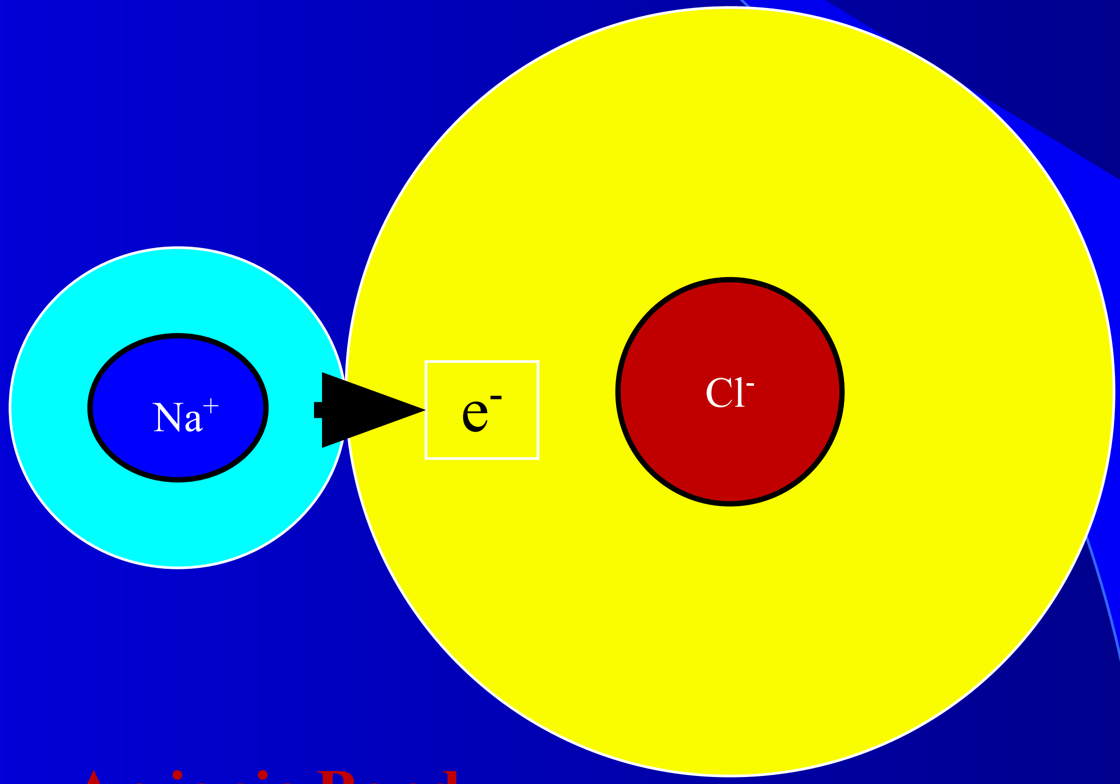
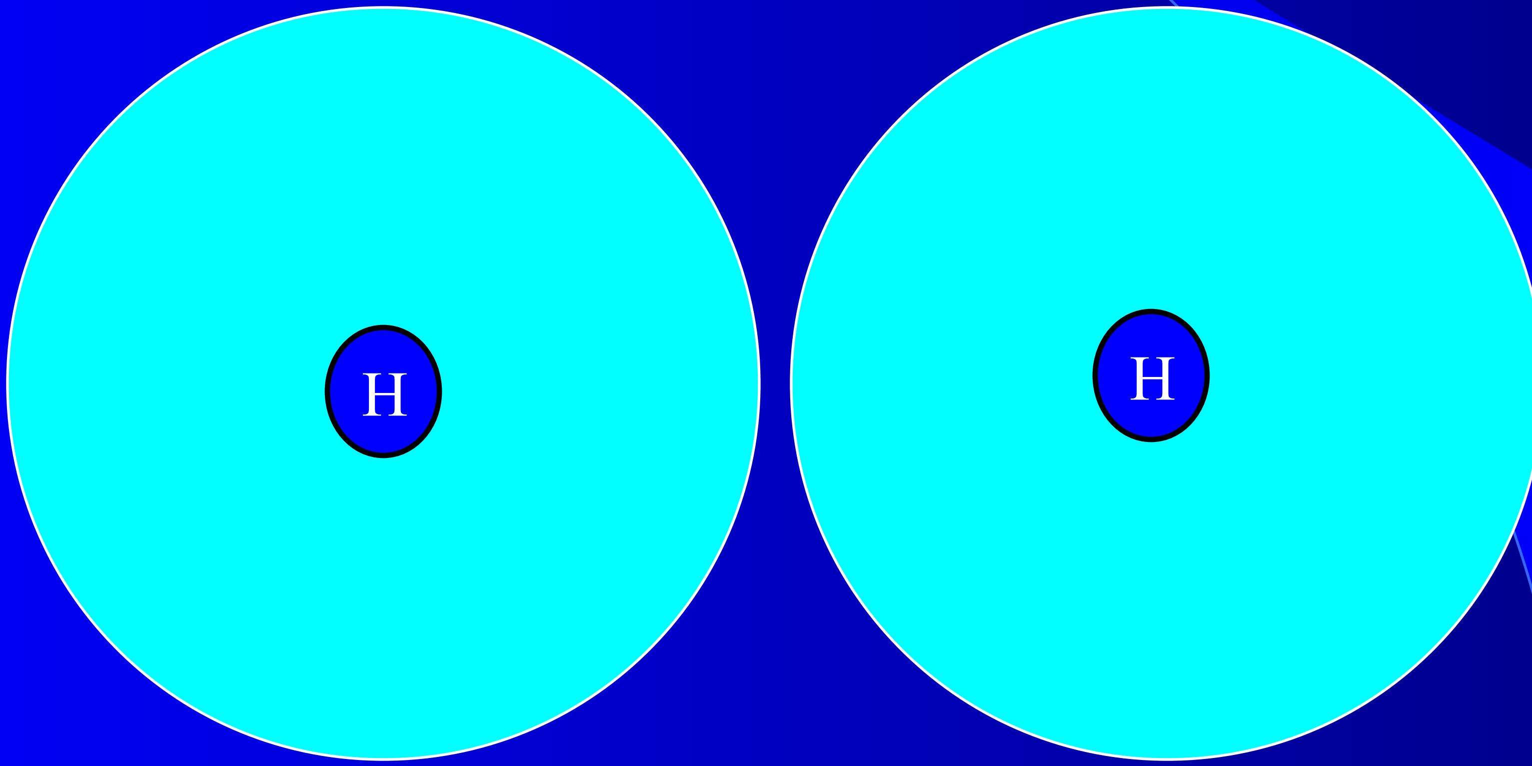


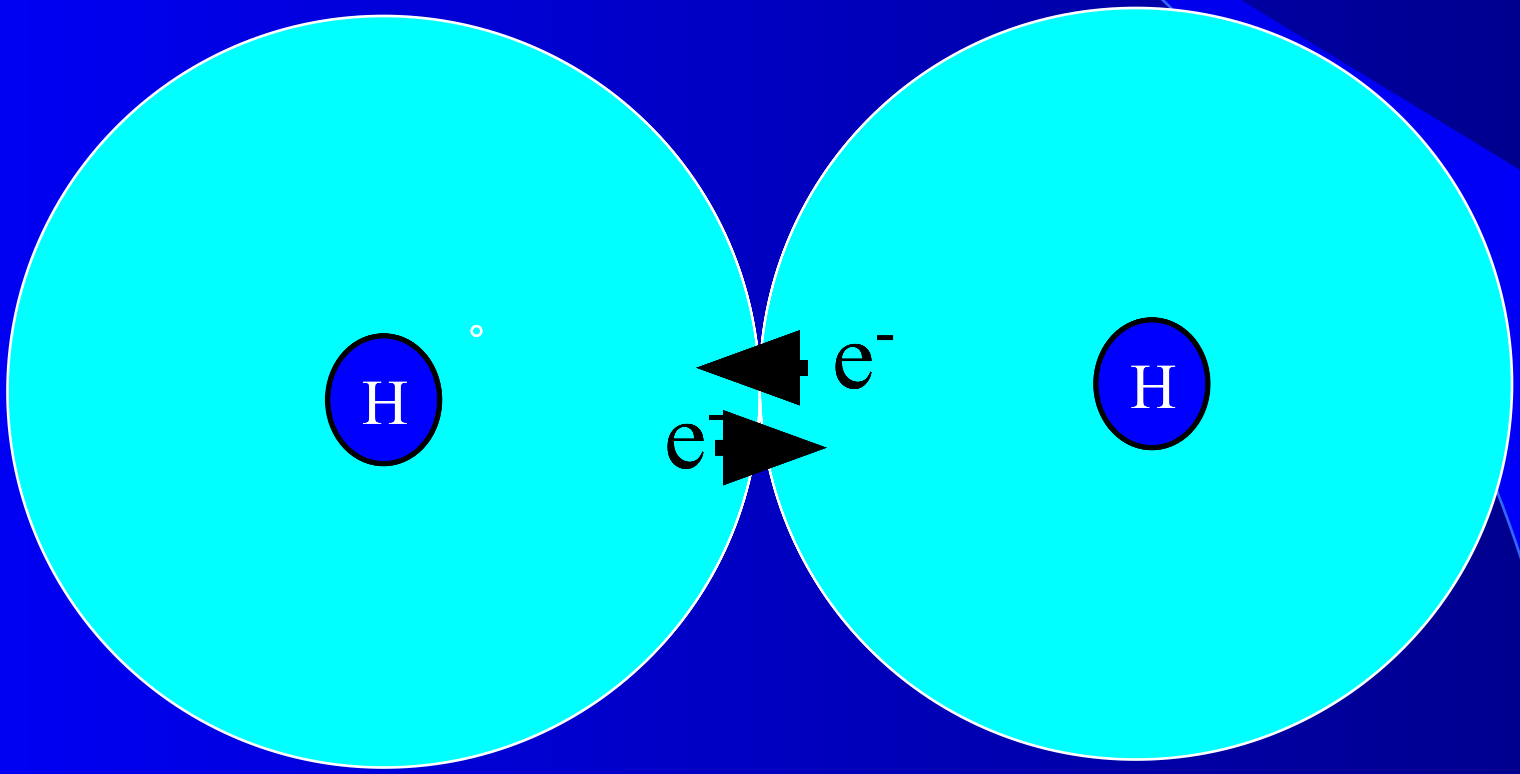
An ionic Bond

When two H-atoms collide…



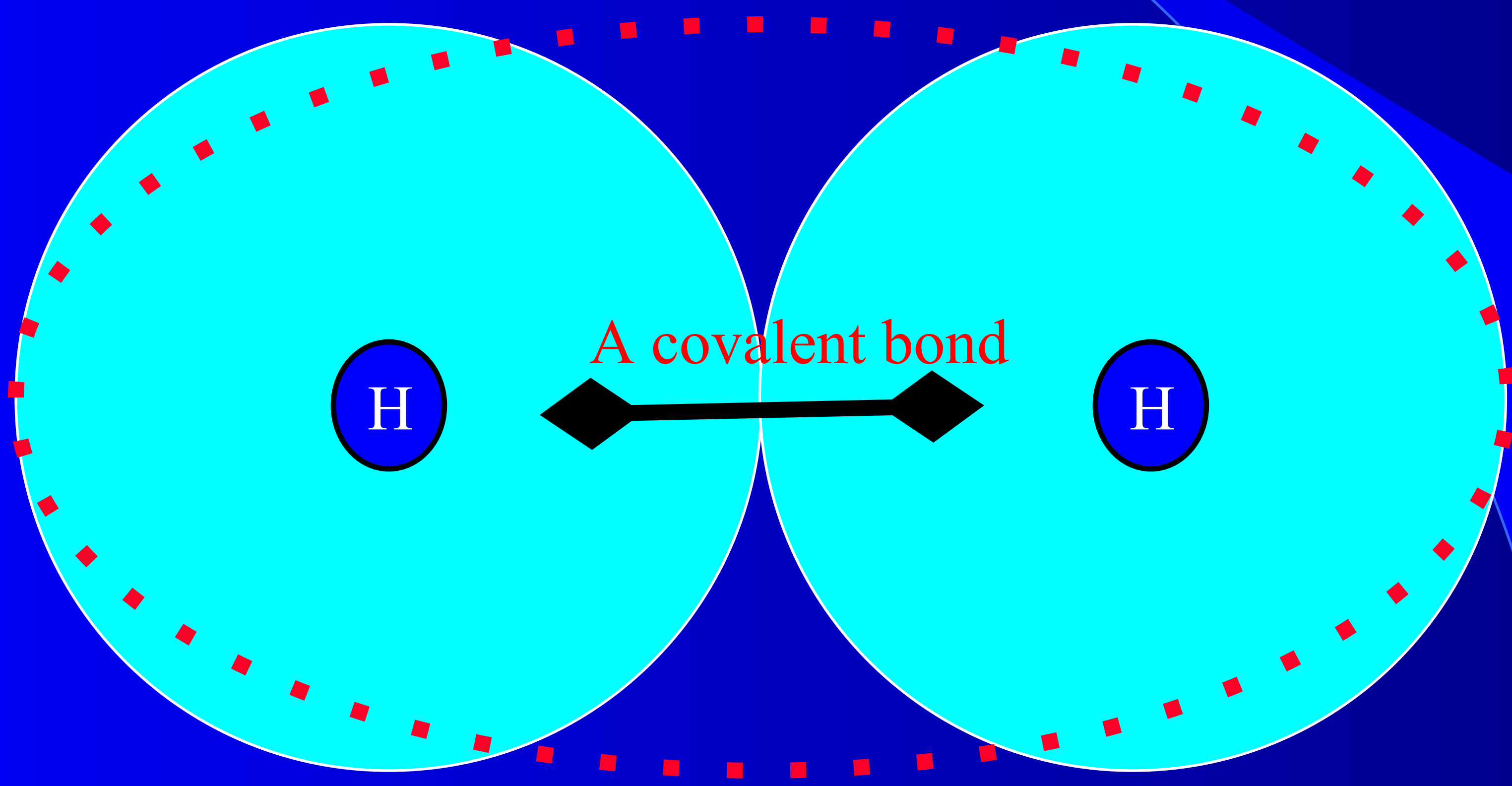
When two H-atoms collide…

Electrons may be shared



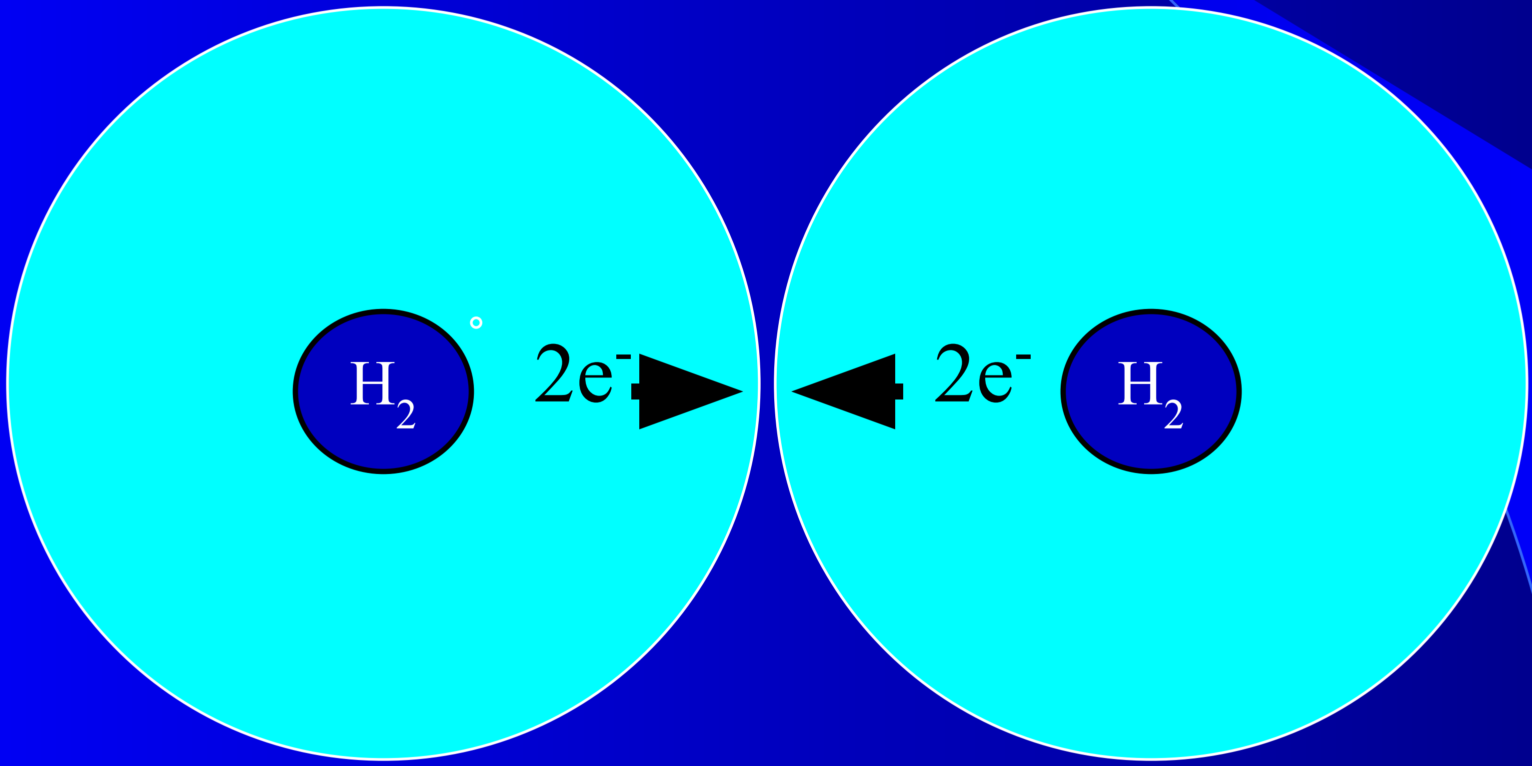
When two H-atoms collide…

Electrons may be shared



When two H_2-molecules collide…

Electrons may repel each other



When two H_2-molecules collide…

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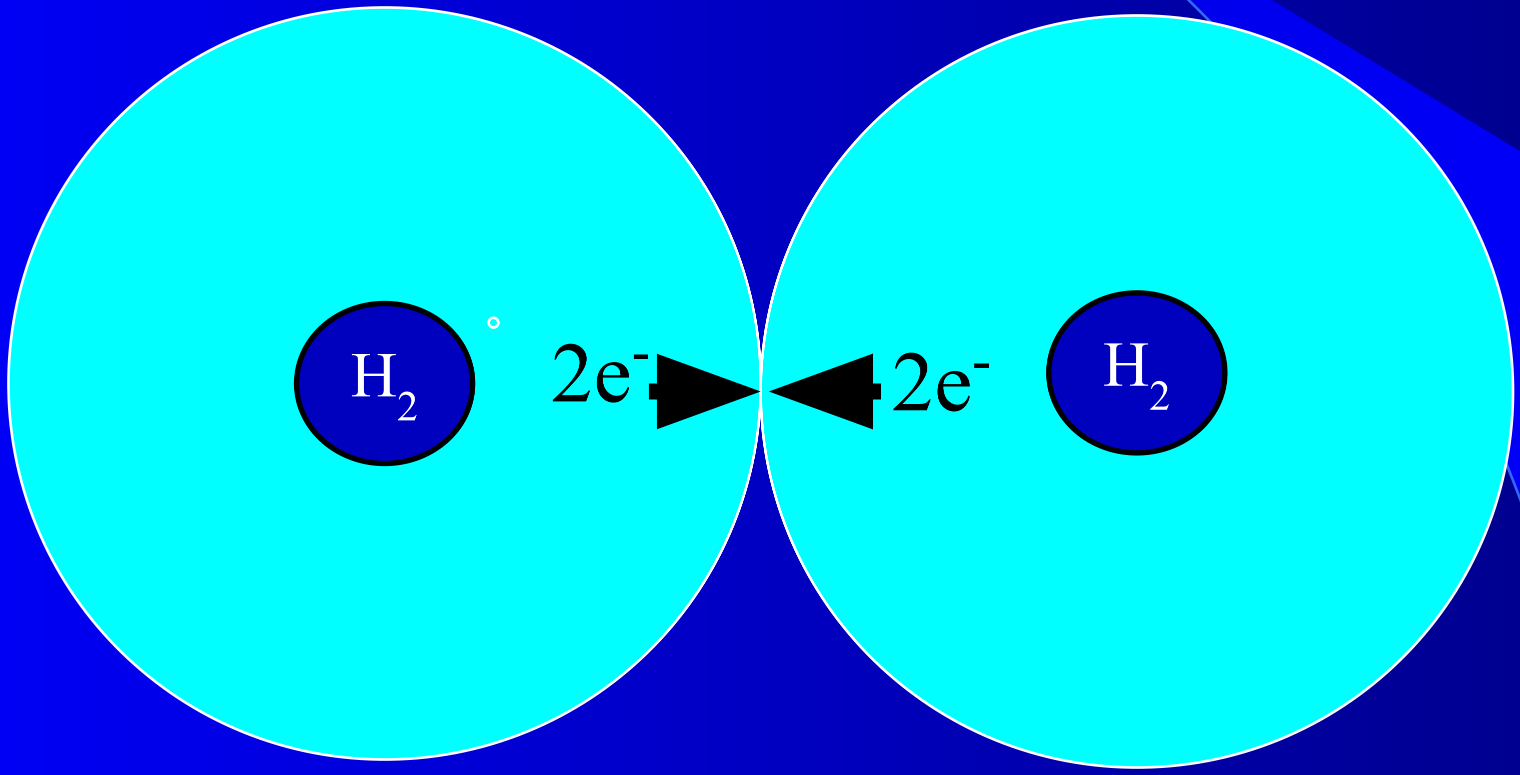
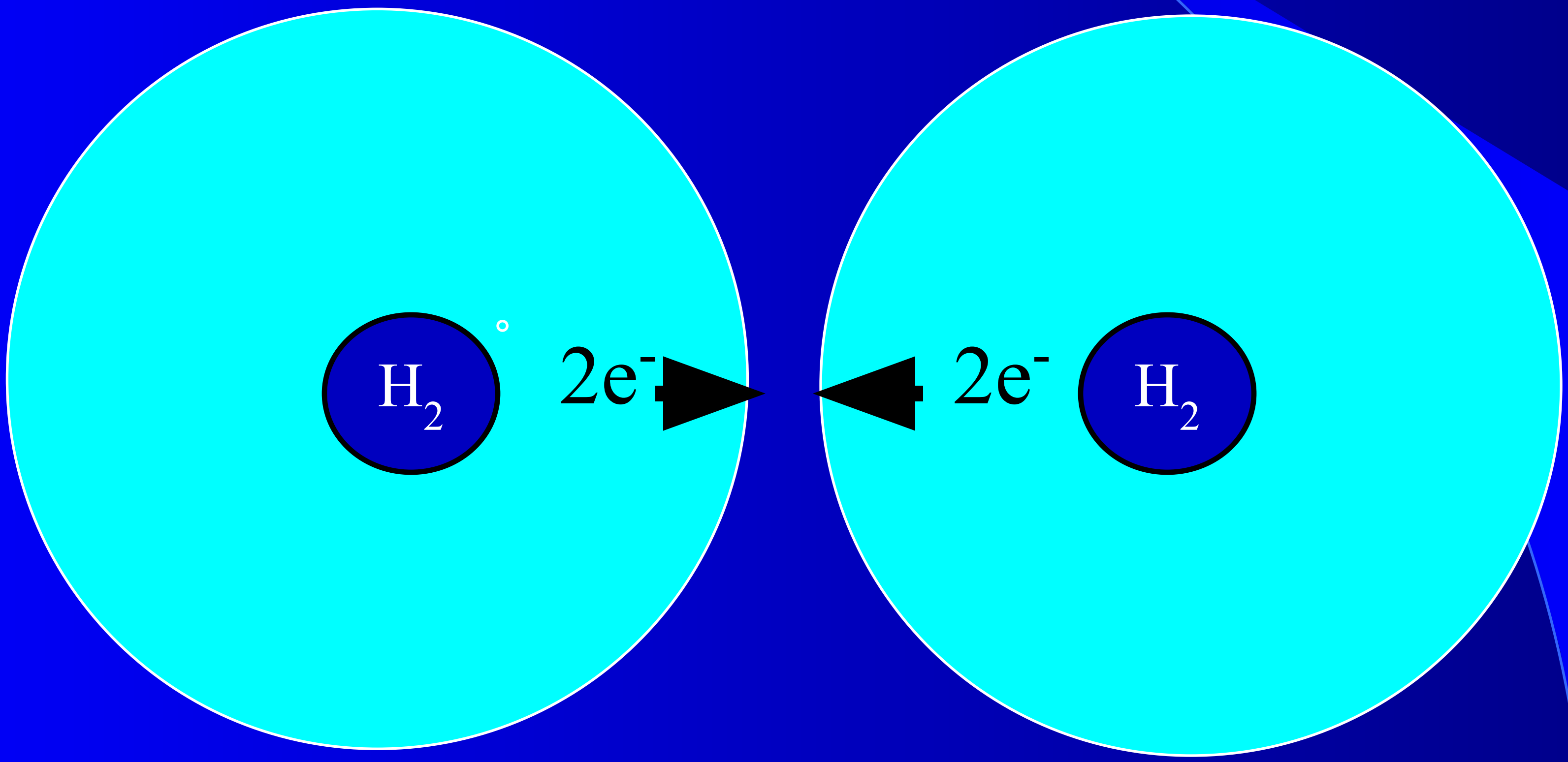


When two H_2-molecules collide…

Electrons may repel each other



When atoms/molecules collide…

We'll study how to predict which of the **<u>Three Possibilities</u>** happens

Chemistry is the central science

Chemistry

Chemistry is the central science

Sub-atomic physics

Chemistry

10^{-10} m

Chemistry is the central science

Sub-atomic physics

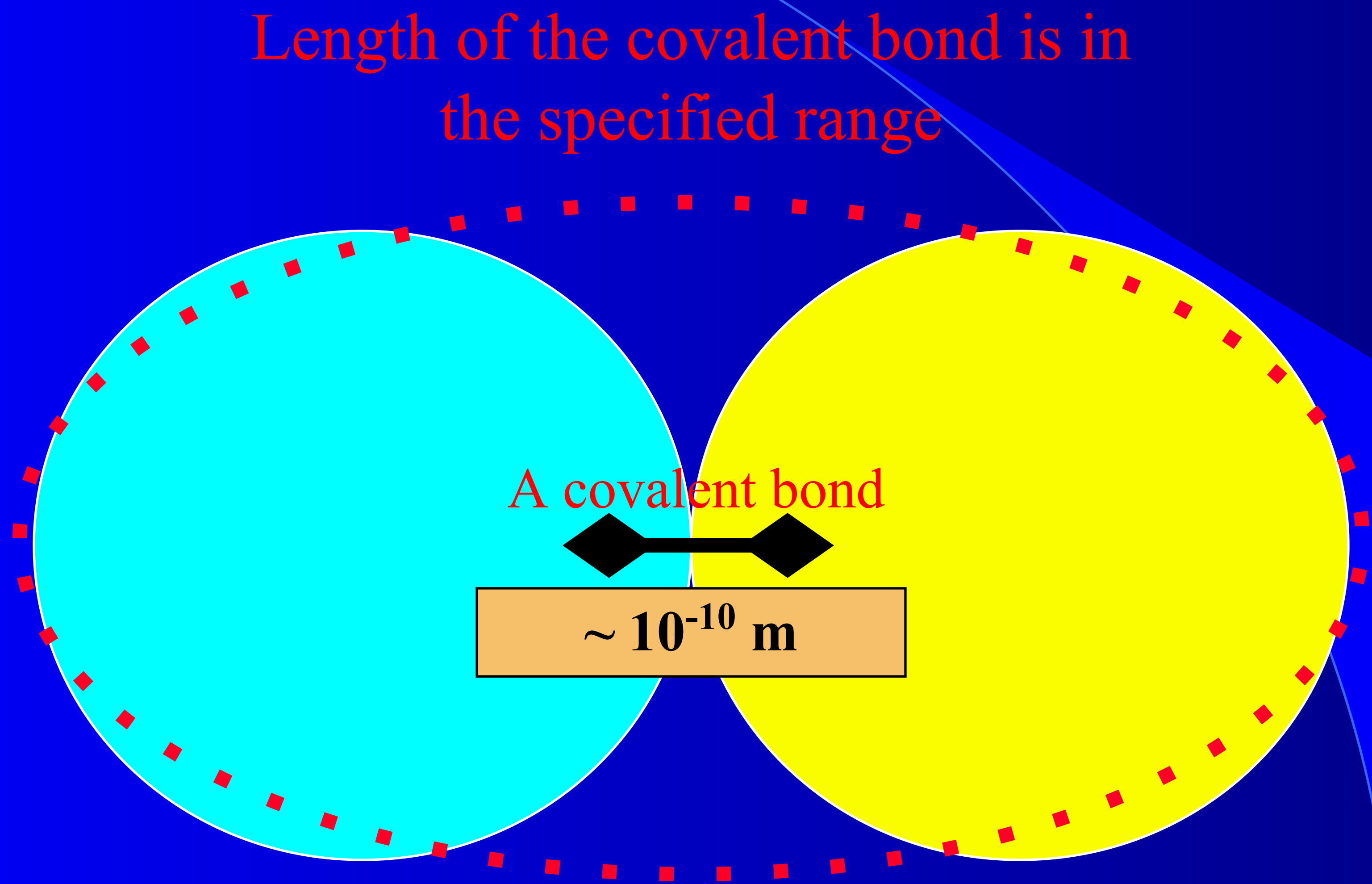
Chemistry

Traditional physics

10^{-10} m

10^{-9} m

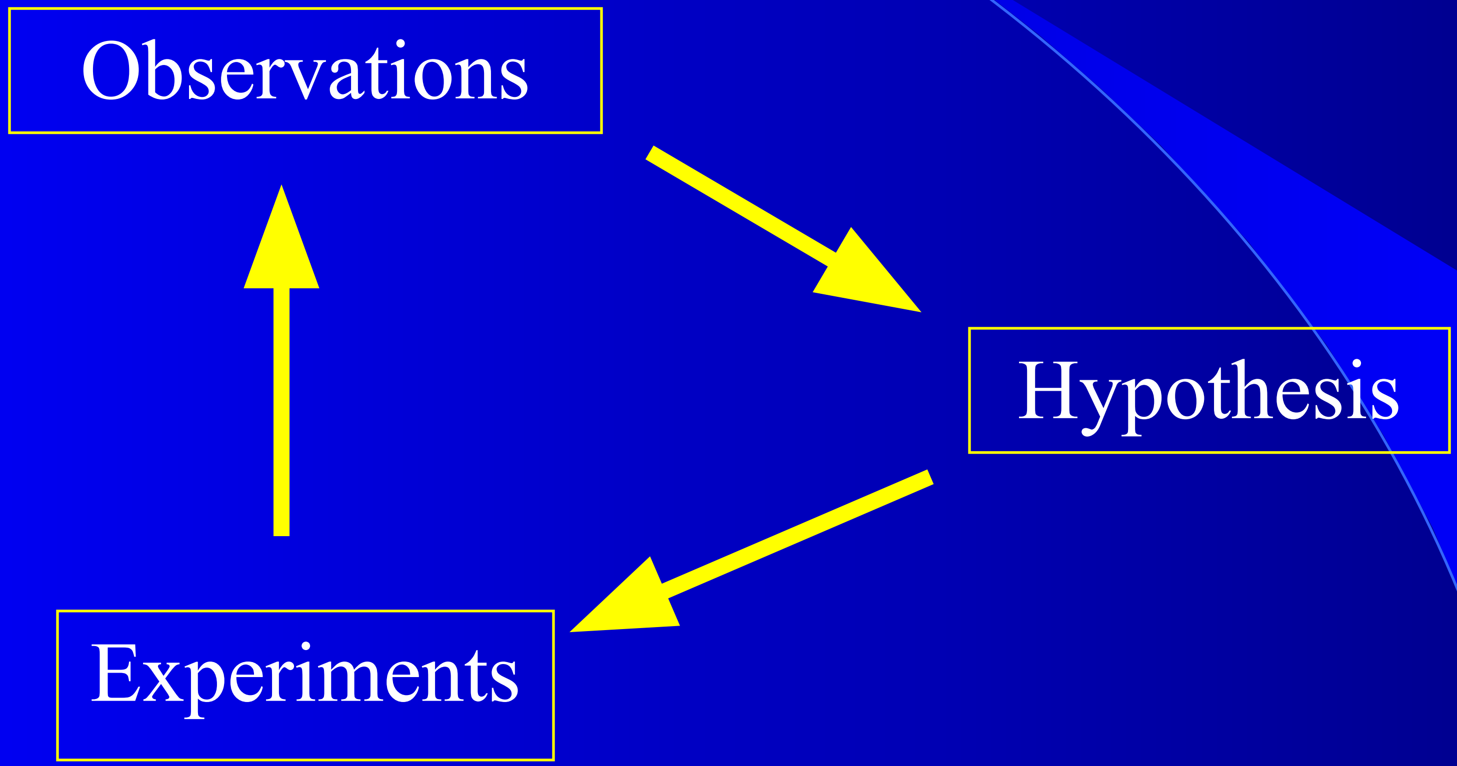
When two atoms/molecules collide…



The Scientific Method

- Science is dynamic -- it's just our "current understanding"
- Involves observation and measurements
- Science attempts to identify variables that control a situation
- The lack of scientific understanding leaves you vulnerable to being duped.

The Scientific Method



Two aspects of chemical reactions...

- Kinetics - how fast the reaction occurs

&

- Thermodynamics - the direction in which the reaction proceeds and the degree of completeness when the action stops

Matter

- Has mass (measured as weight)
- Occupies space (measured as volume)

- # Energy

- Rest of the “normal stuff” in the universe is energy, e.g., light
- Matter and energy are related

$$E = mc^2$$

Modern astrophysics suggests…

- Matter and energy are about 5% of the universe
- Dark matter is another 25%
- Dark Energy is the remaining 70%
- Or we don't quite understand how physics works at a universal scale!

Changes in Chemistry

Chemical changes

- Chemical bonds are broken
- Atoms rearrange themselves
- New chemical bonds form

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$C_3H_8 \ + \ 5\ O_2 \ \ \rightarrow$

Propane gas

Molecular oxygen

Chemical changes

- Chemical bonds are broken
- Atoms rearrange themselves
- New chemical bonds form

$$C_3H_8 + 5\,O_2 \rightarrow 3\,CO_2 + 4\,H_2O$$

Propane gas	Molecular oxygen	Carbon dioxide	Water vapor

Physical changes

- Associated with changes in state (gas, liquid, solid, solution)
- No chemical changes occur
  - Water freezes to ice
  - Ice melts to water
  - (It's H_2O before and after)
  - Sugar dissolves in water
  - Water evaporates leaving sugar
  - (It's $C_{12}H_{22}O_{11}$ before and after)

A burning Candle is…

1. A chemical change
2. A physical change
3. Both

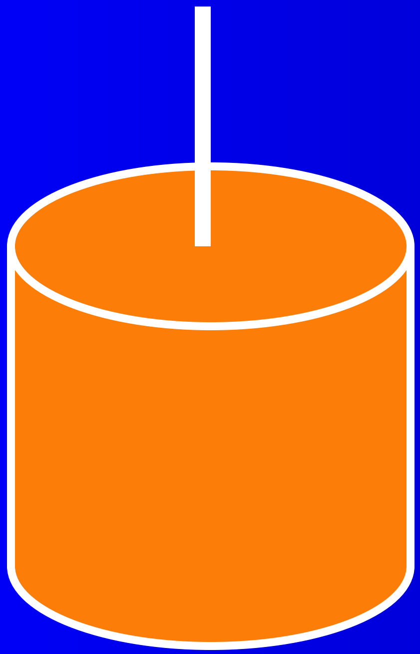
A burning Candle is…

1. A chemical change
2. A physical change
3. Both

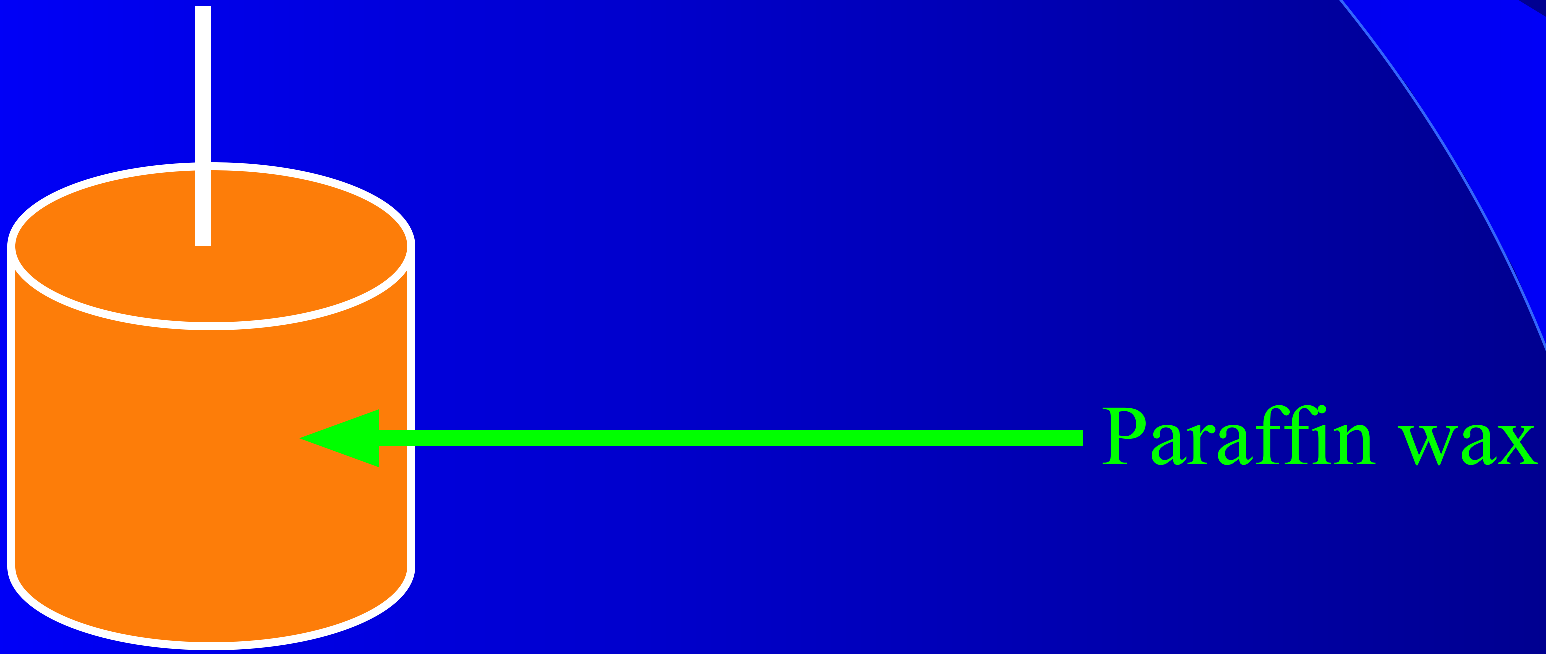
Most real world processes involve both kinds

- When a candle burns…
- Heat from the flame melts (physical change) and pyrolyzes (chemical change) wax components into gaseous vapors
- Vapors burn with oxygen to form carbon dioxide and water (chemical change)

Phases of Fire



Phases of Fire



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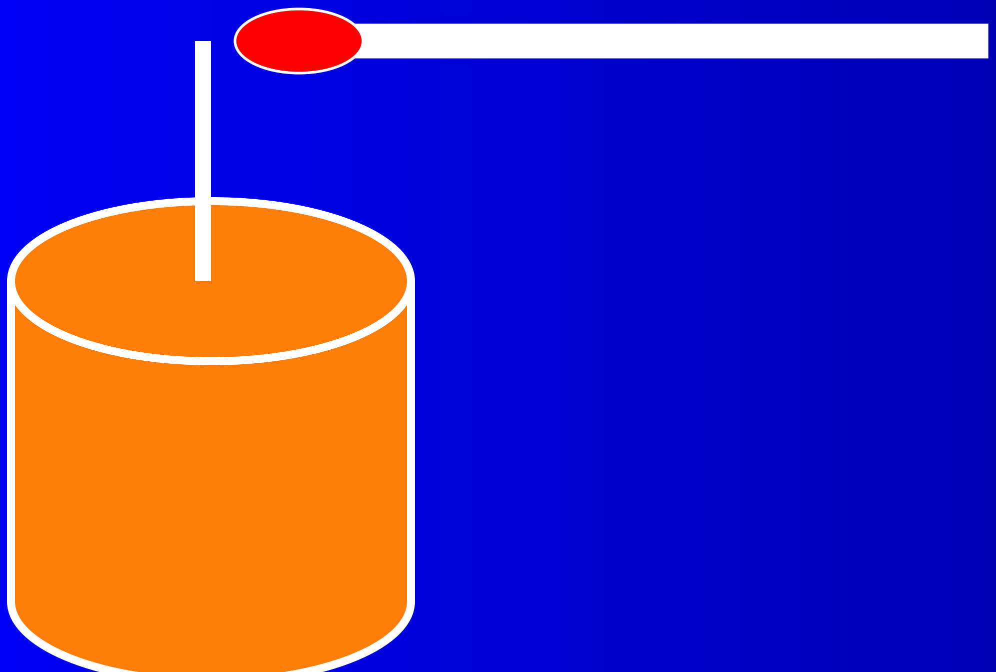

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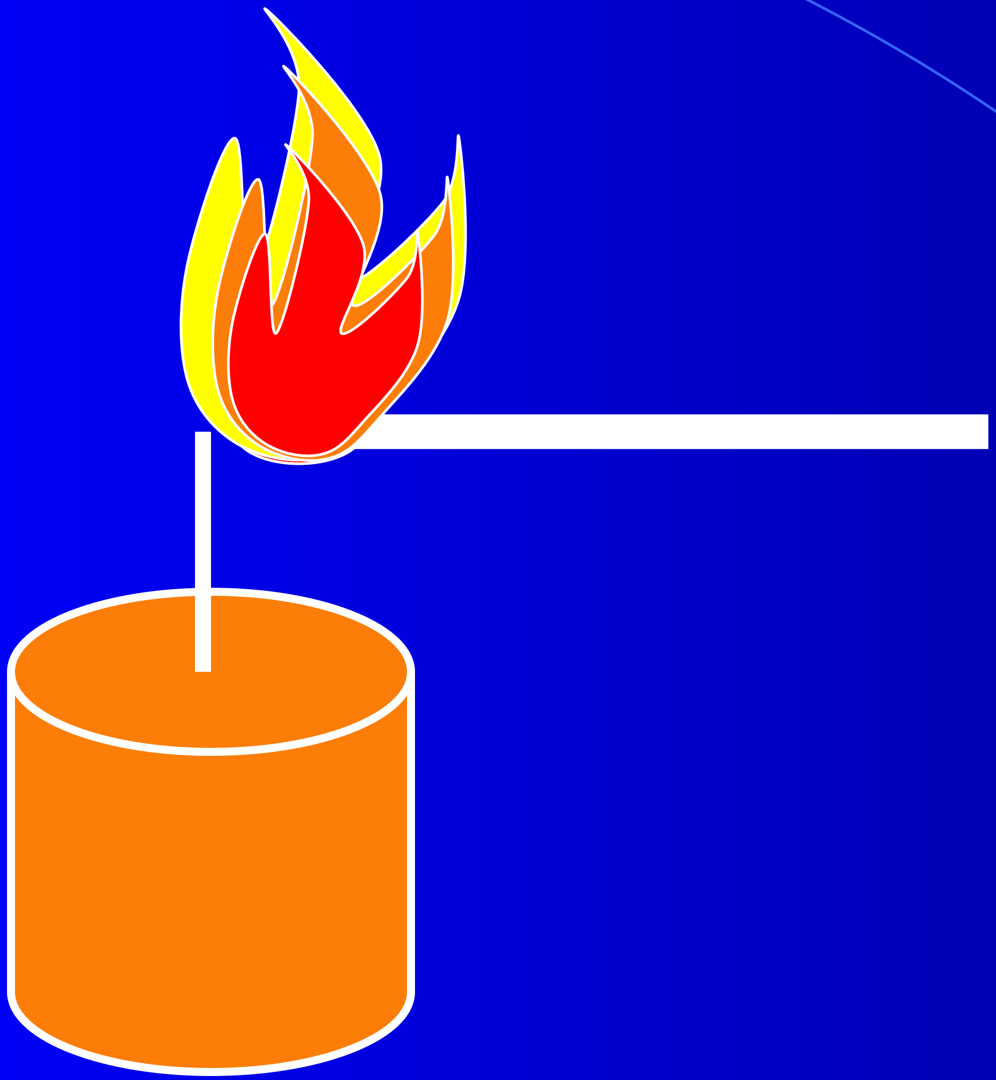

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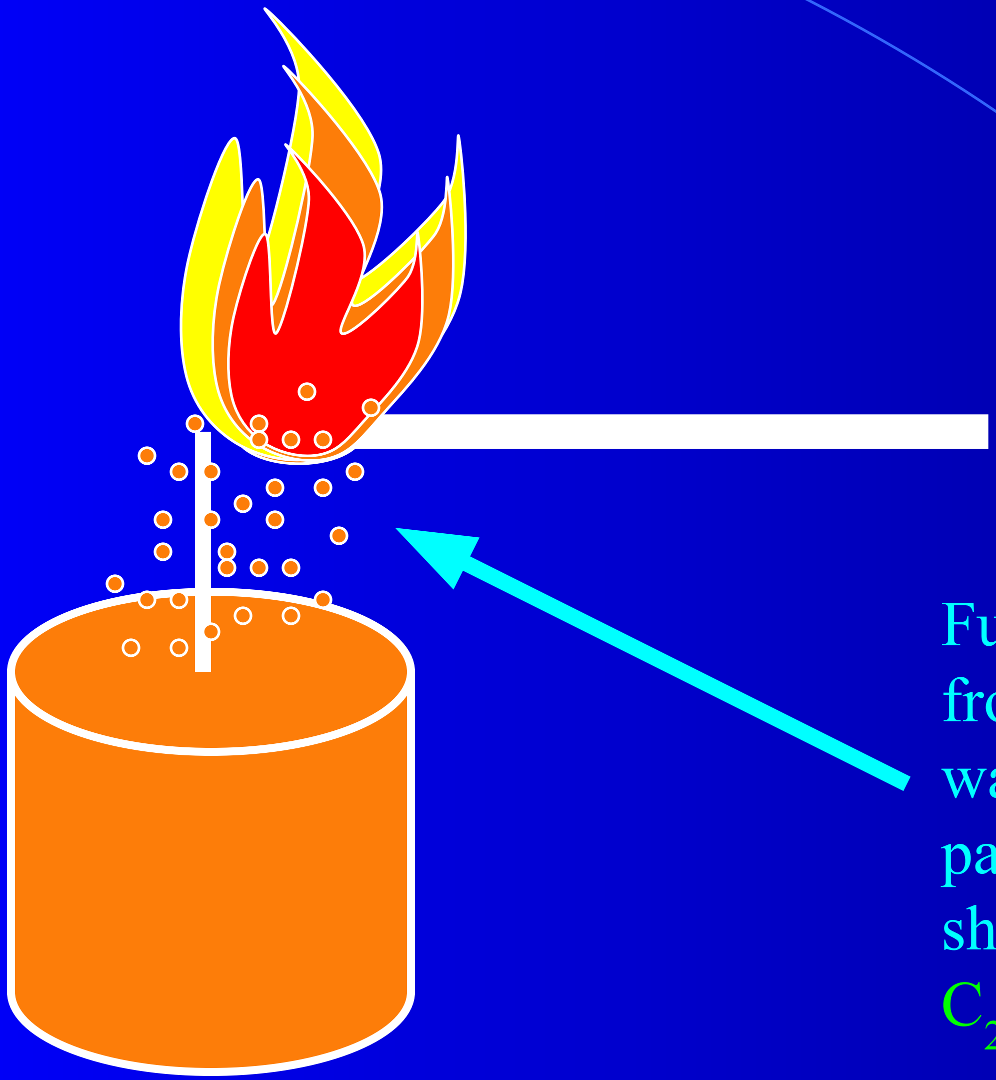
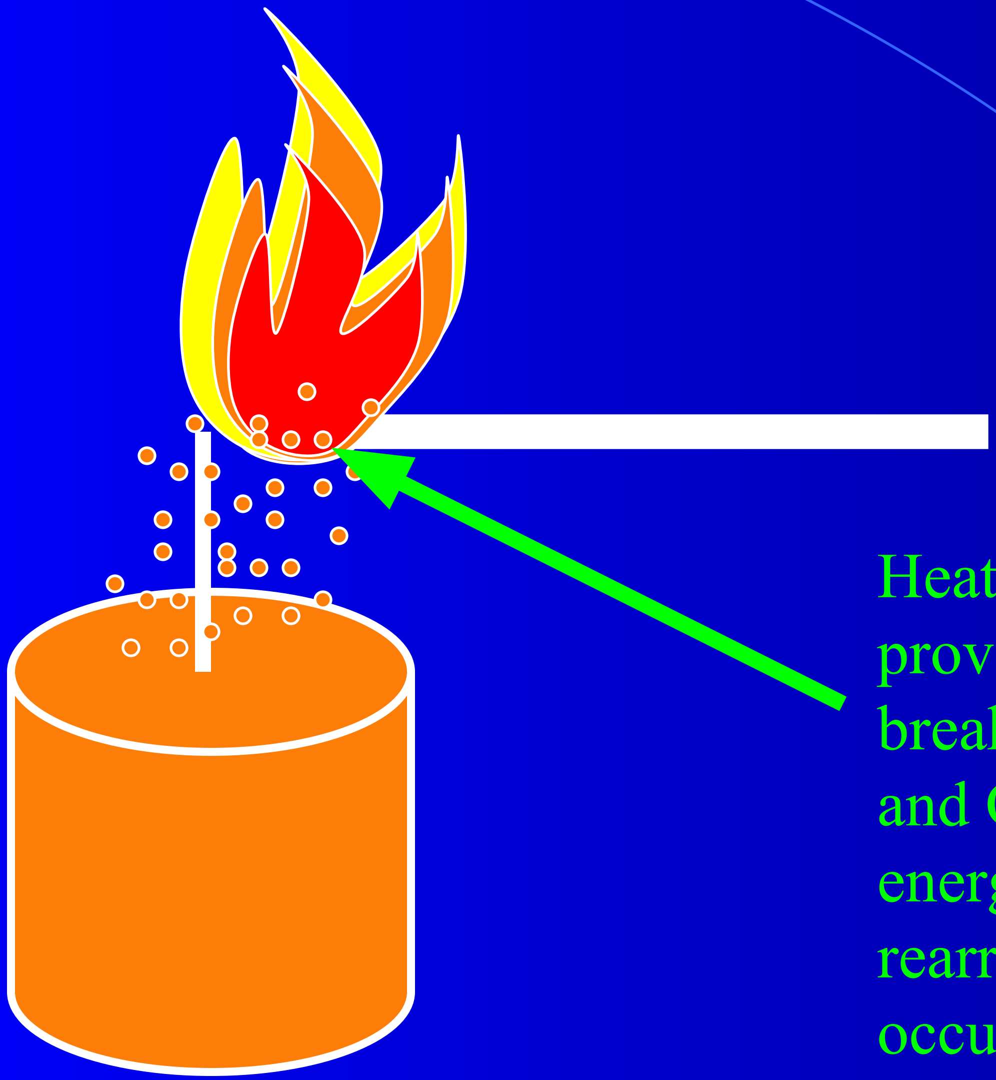


Fuel vapor cloud forms from melting of solid wax and pyrolysis of paraffin wax (e.g., C_{18}) to shorter fragments (e.g., C_2 - C_5)

Phases of Fire

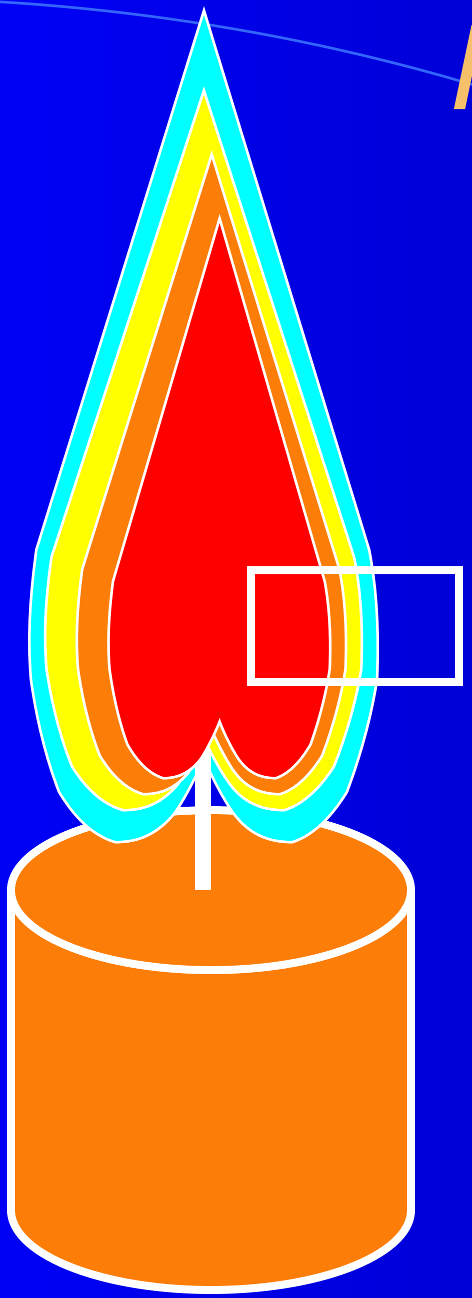


Heat from the flame provides energy to start breaking bonds in fuel and O_2 so that energy-releasing rearrangements can occur

Phases of Fire

A flame forms around the wick as a ball of hot fuel gases that come in contact with the air at the edges

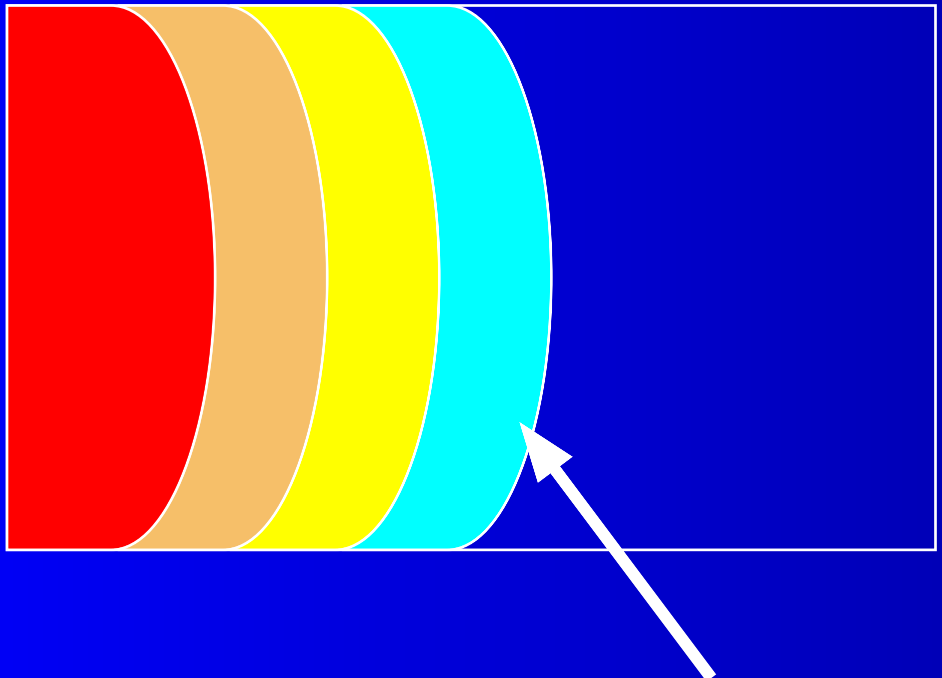
Phases of Fire



Let's zoom in for a closer look here

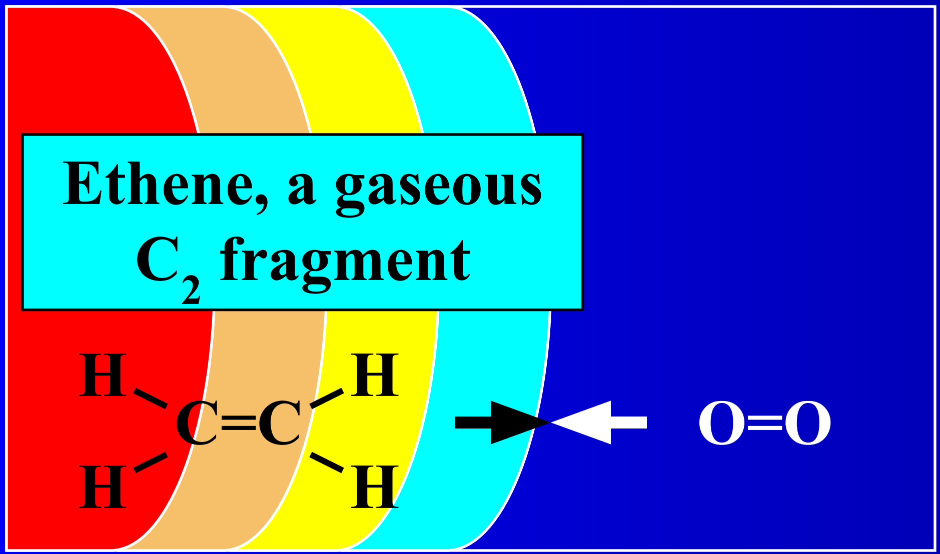
A flame forms around the wick as a ball of hot fuel gases that come in contact with the air at the edges

Phases of Fire



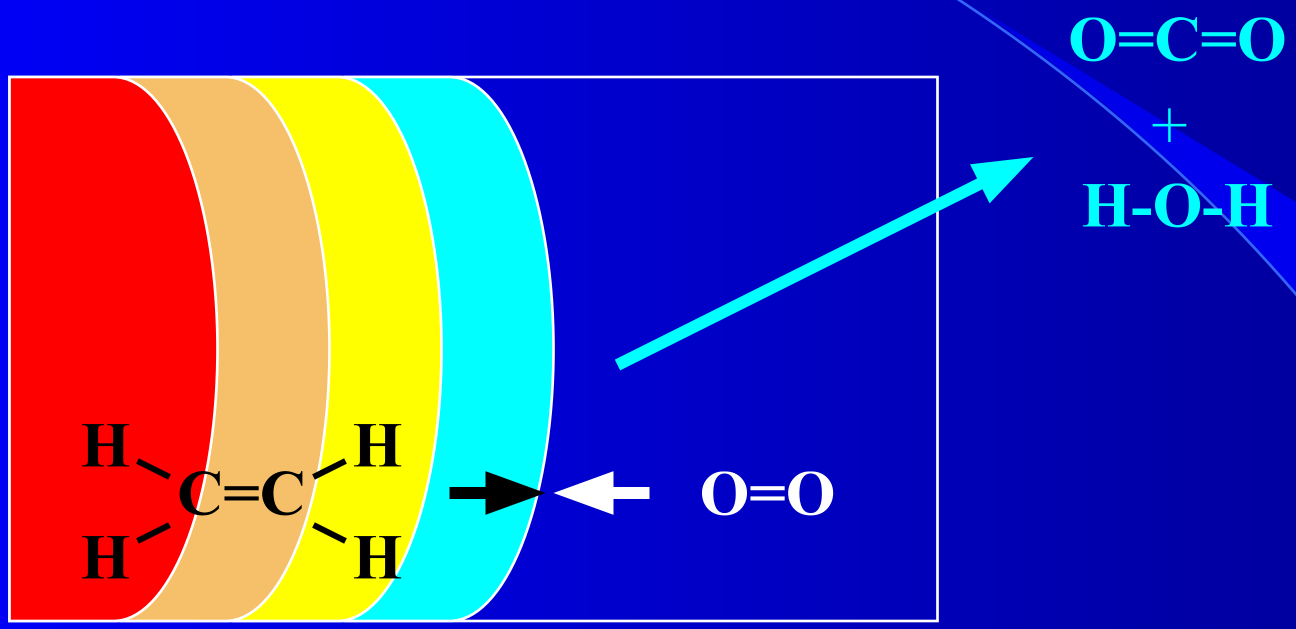
A reaction zone forms where fuel vapors and O_2 come into contact.

Phases of Fire



A **reaction zone** **forms where fuel vapors and O_2 come into contact.**

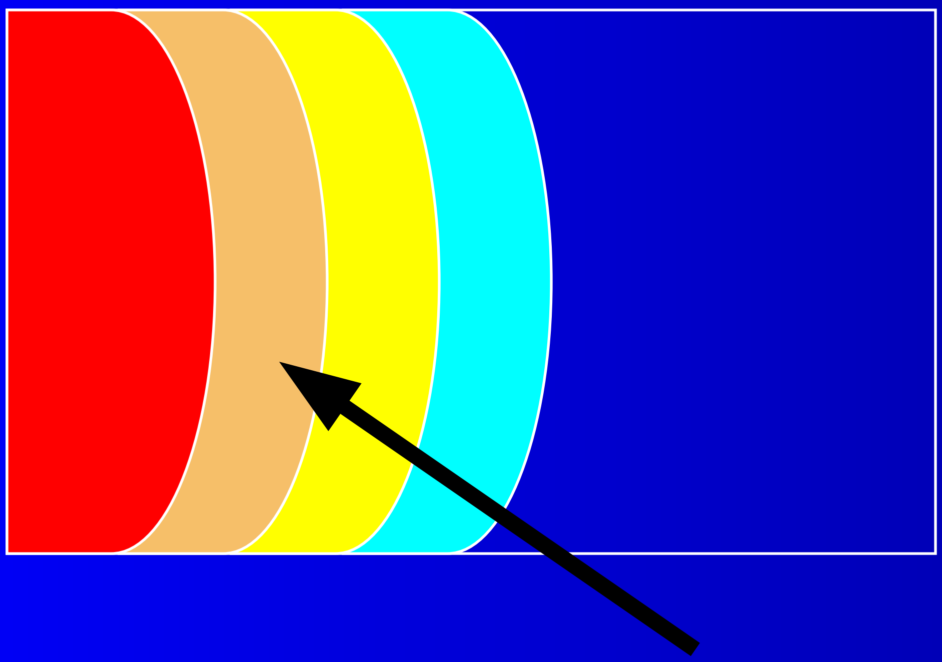
Phases of Fire



CO_2 and H_2O are produced as products. They dissipate in the turbulent mixing above the flame

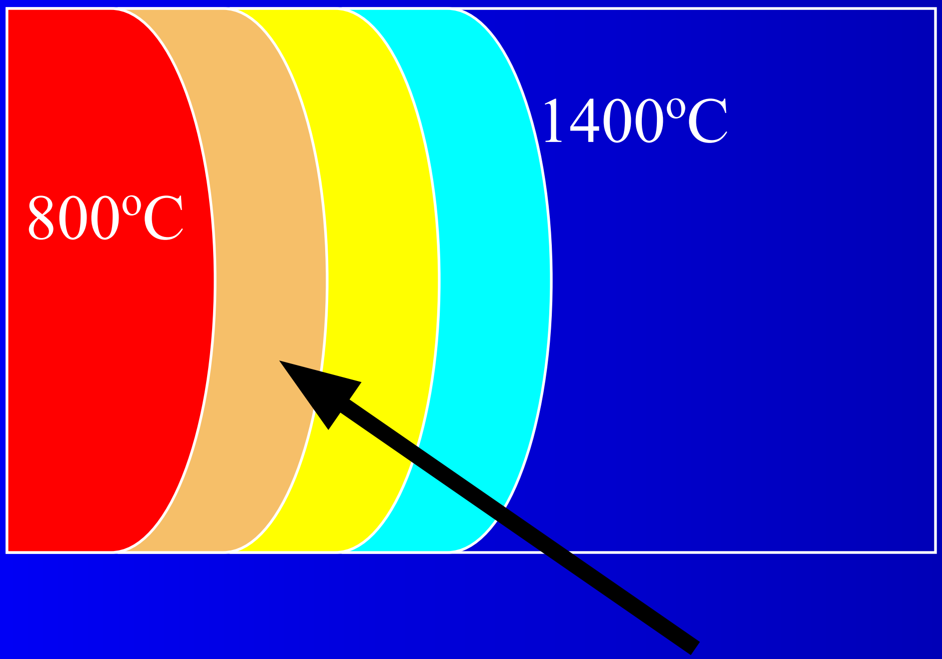

Flaming combustion occurs in the gas phase

Phases of Fire



The interior of the fuel vapor ball contains soot particles (little balls of solid carbon) that are heated to various temperatures -- yellow hotter than orange hotter than red

Phases of Fire



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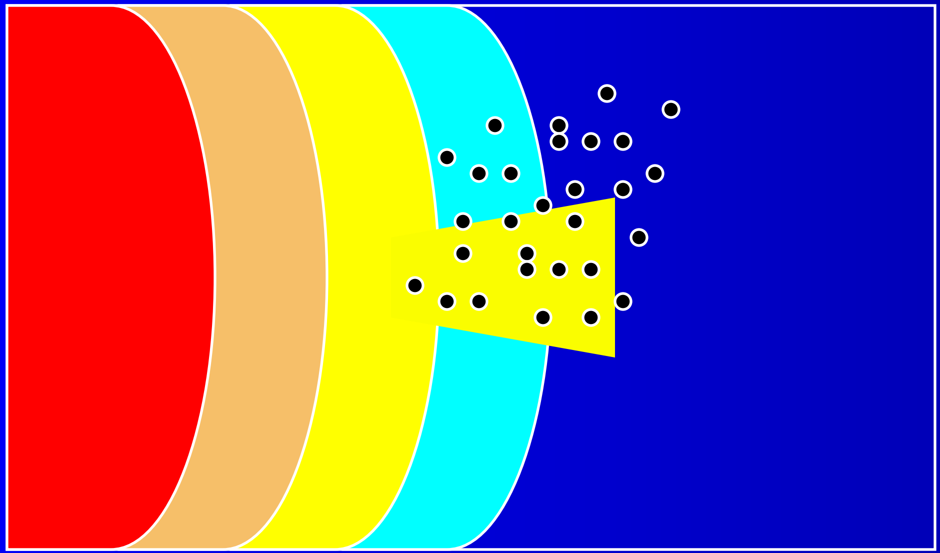


When local turbulence disturbs the reaction zone envelope, some unburned soot particles escape as cool black smoke particulates that are less than 1 micron (micrometer) in diameter


Black soot is most prevalent in turbulent
flaming combustion zones

Numbers in Chemistry

The numbers associated with atoms often get too big or too small to be convenient to write in decimal notation

Exponential Notation

- We'll use exponential notation to make it simpler
- Scientific notation is best for our purposes – it places a decimal after the first non-zero digit

The number of copper atoms in a pre-1982 penny...

The number of copper atoms in a pre-1982 penny...

29 500 000 000 000 000 000 000 atoms

The number of copper atoms in a pre-1982 penny...

29 500 000 000 000 000 000 000 atoms

Place a decimal after the first non-zero digit (to make it scientific notation).

The number of copper atoms in a pre-1982 penny...

29 500 000 000 000 000 000 000 atoms

2.95

Place a decimal after the first non-zero digit (to make it <u>scientific</u> notation).

The number of copper atoms in a pre-1982 penny...

29 500 000 000 000 000 000 000 atoms

2.95

Place a decimal after the first non-zero digit (to make it <u>scientific</u> notation).

The number of copper atoms in a pre-1982 penny...

$$29\ \underbrace{500}_{21}\ \underbrace{000}_{18}\ \underbrace{000}_{15}\ \underbrace{000}_{12}\ \underbrace{000}_{9}\ \underbrace{000}_{6}\ \underbrace{000}_{3}\ \text{atoms}$$

2.95

Now count how many places the decimal has been moved.

The number of copper atoms in a pre-1982 penny...

$$29\ \underbrace{500}_{21}\ \underbrace{000}_{18}\ \underbrace{000}_{15}\ \underbrace{000}_{12}\ \underbrace{000}_{9}\ \underbrace{000}_{6}\ \underbrace{000}_{3}\ \text{atoms}$$

$$2.95 \times 10^{?}\ \text{atoms}$$

Now count how many places the decimal has been moved.

The number of copper atoms in a pre-1982 penny...

$$29\ \underbrace{500}_{21}\ \underbrace{000}_{18}\ \underbrace{000}_{15}\ \underbrace{000}_{12}\ \underbrace{000}_{9}\ \underbrace{000}_{6}\ \underbrace{000}_{3}\ \text{atoms}$$

2.95×10^{22} atoms

Now count how many places the decimal has been moved.

The number of copper atoms in a pre-1982 penny...

$$\mathbf{29\ \underbrace{500}_{21}\ \underbrace{000}_{18}\ \underbrace{000}_{15}\ \underbrace{000}_{12}\ \underbrace{000}_{9}\ \underbrace{000}_{6}\ \underbrace{000}_{3}}\ \text{atoms}$$

2.95×10^{22} atoms

The number of copper atoms in a pre-1982 penny...

$29\ \underbrace{500}_{21}\ \underbrace{000}_{18}\ \underbrace{000}_{15}\ \underbrace{000}_{12}\ \underbrace{000}_{9}\ \underbrace{000}_{6}\ \underbrace{000}_{3}$ atoms

2.95×10^{22} atoms

POSITIVE exponents tell us how many places to the LEFT we've moved.

The number of copper atoms in a pre-1982 penny...

$$\mathbf{29}\ \underbrace{\mathbf{500}}_{21}\ \underbrace{\mathbf{000}}_{18}\ \underbrace{\mathbf{000}}_{15}\ \underbrace{\mathbf{000}}_{12}\ \underbrace{\mathbf{000}}_{9}\ \underbrace{\mathbf{000}}_{6}\ \underbrace{\mathbf{000}}_{3}\ \text{atoms}$$

2.95×10^{22} atoms

Numbers with POSITIVE exponents are BIG

The weight of a single copper atom...

The weight of a single copper atom...

0.000 000 000 000 000 000 000 000 23 lbs

The weight of a single copper atom...

0.000 000 000 000 000 000 000 000 23 lbs

Place a decimal after the first non-zero digit.

The weight of a single copper atom...

0.000 000 000 000 000 000 000 000 23 lbs

2.3

Place a decimal after the first non-zero digit.

The weight of a single copper atom...

0.000 000 000 000 000 000 000 000 23 lbs

2.3

Place a decimal after the first non-zero digit.

The weight of a single copper atom...

0.000 000 000 000 000 000 000 000 23 lbs

2.3

Now count how many places the decimal has been moved.

The weight of a single copper atom...

$$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ \underbrace{000}_{15}\ \underbrace{000}_{18}\ \underbrace{000}_{21}\ \underbrace{000}_{24}\ 23 \text{ lbs}$$

2.3

Now count how many places the decimal has been moved.

The weight of a single copper atom...

$$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ \underbrace{000}_{15}\ \underbrace{000}_{18}\ \underbrace{000}_{21}\ \underbrace{000}_{24}\ 23 \text{ lbs}$$

$$2.3 \times 10^{?} \text{ lbs}$$

Now count how many places the decimal has been moved.

The weight of a single copper atom...

$$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ \underbrace{000}_{15}\ \underbrace{000}_{18}\ \underbrace{000}_{21}\ \underbrace{000}_{24}\ 23 \text{ lbs}$$

$$2.3 \times 10^{-25} \text{ lbs}$$

Now count how many places the decimal has been moved.

The weight of a single copper atom...

$$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ \underbrace{000}_{15}\ \underbrace{000}_{18}\ \underbrace{000}_{21}\ \underbrace{000}_{24}\ 23 \text{ lbs}$$

2.3×10^{-25} lbs

NEGATIVE exponents tell us how many places to the RIGHT we've moved.

The weight of a single copper atom...

$$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ \underbrace{000}_{15}\ \underbrace{000}_{18}\ \underbrace{000}_{21}\ \underbrace{000}_{24}\ 23 \text{ lbs}$$

$$2.3 \times 10^{-25} \text{ lbs}$$

Numbers with NEGATIVE exponents are SMALL

The correct scientific notation for 0.000 000 000 000 041 is…

1. 41×10^{-15}
2. 4.1×10^{14}
3. 4.1×10^{-14}
4. 4.1×10^{-15}

The correct scientific notation for $0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ 041$ is…

1. 41×10^{-15}
2. 4.1×10^{14}
3. 4.1×10^{-14}
4. 4.1×10^{-15}

The correct scientific notation for 0.000 000 000 000 041 is…

$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ 041$

1. 41×10^{-15}
2. 4.1×10^{14}
3. $\boxed{4.1 \times 10^{-14}}$
4. 4.1×10^{-15}

14 places to the right

scientific notation

The correct scientific notation for 0.000 000 000 000 041 is…

$$0.\underbrace{000}_{3}\ \underbrace{000}_{6}\ \underbrace{000}_{9}\ \underbrace{000}_{12}\ 041$$

1. $\boxed{41 \times 10^{-15}}$
2. 4.1×10^{14}
3. 4.1×10^{-14}
4. 4.1×10^{-15}

15 places to the right

engineering notation (the exponent is evenly divisible by three)

Calculations with scientific notation

- Rules are given in any standard textbook
- Different rules apply for multiplication/division vs. addition/subtraction
- Most common error is entering scientific notation on your calculator
- Need to learn the “exp” or “EE” key or the “$x10^x$” key

Entering scientific notation…

Entering scientific notation…

To enter 6.02×10^{23}

Entering scientific notation…

To enter 6.02×10^{23}

Press...

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

Entering scientific notation…

To enter 6.02 x 10^{23}

Press...

6

.

0

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

0

2

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

0

2

"exp" or "EE" or "x10^{x}"

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

0

2

"exp" or "EE" or "$x10^x$"

On many calculators this is a "2^{nd} + EE" sequence where EE means "Enter Exponent"

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

0

2

"exp" or "EE" or "$x10^x$"

2

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

0

2

"exp" or "EE" or "x10^x"

2

3

Entering scientific notation…

To enter 6.02×10^{23}

Press...

6

.

0

2

"exp" or "EE" or "$x10^x$"

2

3

Notice that there is no "x 10" in this sequence unless you have the "$x10^x$" key!

Entering scientific notation…

To enter 6.02×10^{23}

Press...
6
.
0
2
“exp” or “EE” or “$x10^x$”
2
3

Say “x 10” as you press the “exp” or “EE” key

Entering scientific notation…

To enter 6.02×10^{23}

Press...
6
.
0
2
"exp" or "EE" or "$x10^x$"
2
3

They should have marked the key "$x10^x$", but they didn't ask me!

Entering scientific notation…

To enter 6.02×10^{23}

Calculators with fancy screens (like TI-84's) do let you enter this as

6 . 0 2 x 1 0 ^ 2 3

Entering scientific notation…

To enter 6.02×10^{23}

Calculators with fancy screens (like TI-84's) do let you enter this as

6 . 0 2 x 1 0 ^ 2 3

But that's 2 or 3 more key strokes and requires lots of extra parens during calculations!

Entering scientific notation…

- However you enter it, the correct result of your calculator display after you press ENTER should look something like one of these:

$$6.02^{23} \quad \text{or} \quad 6.02\text{E } 23$$

$$\text{or} \quad 6.02\text{e}{+}23$$

Entering scientific notation…

- However you enter it, the correct result of your calculator display after you press ENTER should look something like one of these:

6.02^{23} or 6.02E 23

or 6.02e+23

If your display reads 6.02^{24} or 6.02e24, you blew it (x10)!

We’ll do calculations like...

We'll do calculations like...

$$\frac{(3.5 \times 10^{3})^{2}}{4.1 \times 10^{-4}}$$

We'll do calculations like...

$$\frac{(3.5 \times 10^{3})(3.5 \times 10^{3})}{4.1 \times 10^{-4}} = \frac{1.225 \times 10^{7}}{4.1 \times 10^{-4}}$$

$$= 2.987804878 \times 10^{10}$$


FOREVER USA
T.rex

FOREVER USA
T.rex

FOREVER USA
T.rex

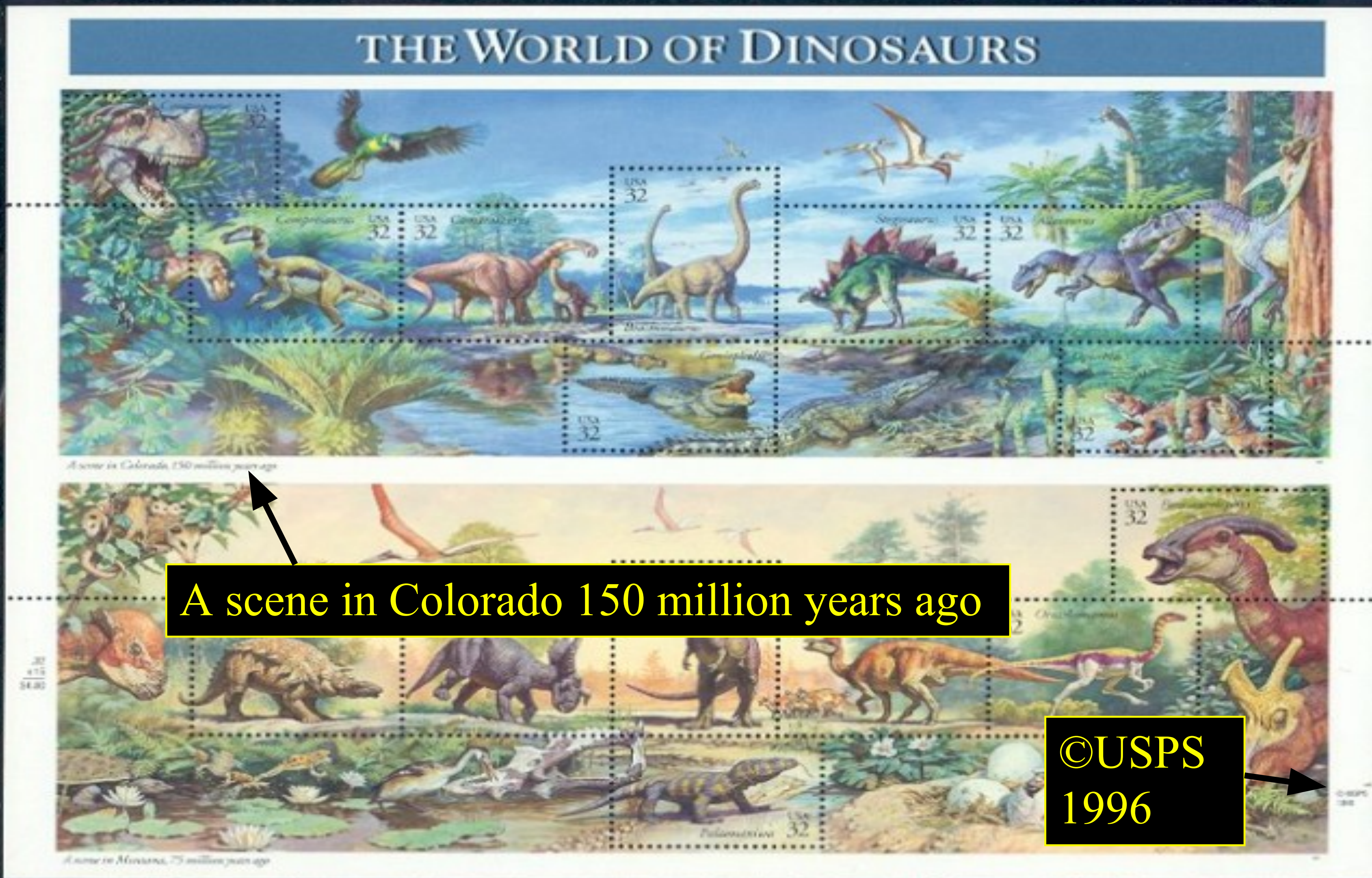
FOREVER USA
T.rex

Tyrannosaurus Rex Forever Stamps
Aug. 29, 2019

*D*iscovered on federal land in Montana ***Tyrannosaurus rex*** dominated the tail end of the dinosaur age.

Significant Figures

- The USPS issued a dinosaur stamp sheet in 1996 also
- The stamp sheet reads “A scene in Colorado 150,000,000 years ago”



The World of Dinosaur stamps was issued on May 1, 1997 in Grand Junction, Colorado, USA. This set of fifteen U.S stamps feature prehistoric dinosaurs from North America during Jurassic and Cretaceous periods.

Significant Figures

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- The stamp sheet reads “A scene in Colorado 150,000,000 years ago”
- Since it’s now 2020, shouldn’t we say “A scene in Colorado 150,000,024 years ago”?

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- Significant figures do not include uncertain digits or place-holding zeroes.

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- Significant figures do not include uncertain digits or place-holding zeroes.

Significant Figures

- The USPS issued a dinosaur stamp sheet in 1996
- The stamp sheet reads "A scene in Colorado **150,000,000** years ago"
- Since it's now 2020, shouldn't we say "A scene in Colorado **150,000,024** years ago"
- Significant figures do not include uncertain digits or place-holding zeroes.

Only 2 significant figures

We'll do calculations like...

$$\frac{(3.5 \text{ x } 10^{3})(3.5 \text{ x } 10^{3})}{4.1 \text{ x } 10^{-4}} = \frac{1.225 \text{ x } 10^{7}}{4.1 \text{ x } 10^{-4}}$$

$$= 2.987804878 \text{ x } 10^{10}$$

Values used only have two significant figures

We'll do calculations like...

$$\frac{(3.5 \times 10^{3})(3.5 \times 10^{3})}{4.1 \times 10^{-4}} = \frac{1.225 \times 10^{7}}{4.1 \times 10^{-4}}$$

$$= 2.987804878 \times 10^{10}$$

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$$\frac{(3.5 \times 10^{3})(3.5 \times 10^{3})}{4.1 \times 10^{-4}} = \frac{1.225 \times 10^{7}}{4.1 \times 10^{-4}}$$

Values used only have two significant figures

$$= 2.9\underline{87804878} \times 10^{10}$$

Uncertain digits

We'll do calculations like...

$$\frac{(3.5 \times 10^{3})(3.5 \times 10^{3})}{4.1 \times 10^{-4}} = \frac{1.225 \times 10^{7}}{4.1 \times 10^{-4}}$$

$$= 2.987804878 \times 10^{10}$$

$$= 3.0 \times 10^{10}$$

Two significant figures in our answer

We'll do calculations like...

$$\frac{(3.5 \times 10^{3})(3.5 \times 10^{3})}{4.1 \times 10^{-4}} = \frac{1.225 \times 10^{7}}{4.1 \times 10^{-4}}$$

$$= 2.987804878 \times 10^{10}$$

This requires rounding

$$= 3.0 \times 10^{10}$$

We'll do calculations like...

$$\frac{(3.5 \times 10^{3})(3.5 \times 10^{3})}{4.1 \times 10^{-4}} = \frac{1.225 \times 10^{7}}{4.1 \times 10^{-4}}$$

$$= 2.987804878 \times 10^{10}$$

$$= 3.0 \times 10^{10}$$

Significant Figure Practice

- Determining significant figures is a snap
- No decimal present? Toss out any trailing zeroes
- Decimal present? Toss out any leading zeroes

How many sig figs in 0.0003007?

1. 2
2. 4
3. 7
4. 8

How many sig figs in 0.0003007?

1. 2
2. 4
3. 7
4. 8

Significant Figure Practice

- 0.000**3007** (4 sig figs)

Significant Figure Practice

- 0.000**3007** (4 sig figs)

A decimal is present so we drop the leading zeroes

How many sig figs in 15.00?

1. 2
2. 3
3. 4

How many sig figs in 15.00?

1. 2
2. 3
3. $\boxed{4}$

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)

A decimal is present but there are no leading zeroes to drop!

How many sig figs in 1200?

1. 2
2. 3
3. 4

How many sig figs in 1200?

1. 2
2. 3
3. 4

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)
- **12**00 (2 sig figs)

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)
- **12**00 (2 sig figs)

No decimal present so we drop trailing zeroes

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)
- 1200 (2 sig figs)

What if there were actually 3 or 4 sig figs?

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)
- 1200 (2 sig figs)

What if there were actually 3 or 4 sig figs?

1.2×10^3 (2 sig figs) 1.20×10^3 (3 sig figs)

1.200×10^3 (4 sig figs)

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)
- 1200 (2 sig figs)

All figs are sig in scientific notation!!!!!!

1.2×10^3 (2 sig figs) 1.20×10^3 (3 sig figs) 1.200×10^3 (4 sig figs)

Significant Figure Practice

- 0.000**3007** (4 sig figs)
- **15.00** (4 sig figs, we wouldn't have written those last two zero's if they weren't measurable)
- 1200 (2 sig figs)

Decimal present but no leading zeroes

1.2×10^3 (2 sig figs) 1.20×10^3 (3 sig figs) 1.200×10^3 (4 sig figs)

Try this one now

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} = ?$$

1. 6.6×10^{-7}
2. 6.6159×10^{-13}
3. 2.2×10^{-2}
4. 6.6×10^{-13}

Try this one now

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} = ?$$

1. 6.6×10^{-7}
2. 6.6159×10^{-13}
3. 2.2×10^{-2}
4. $\boxed{6.6 \times 10^{-13}}$

Try this one now...

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} =$$

Try this one now...

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} =$$

$6.615942028986 \times 10^{-13}$

Here's the button sequence I would use:

8 . 3 0 2nd EE (-) 4 x 5 . 5 2nd EE (-) 6 ÷ 6 . 9 2nd EE 3

Try this one now...

3 sig. figs.

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} =$$

2 sig. figs.

$6.615942028986 \times 10^{-13}$

Our answer should have no more sig figs than any of our starting values

Try this one now...

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} =$$

$\boxed{\text{2 sig. figs.}}$

$6.615942028986 \times 10^{-13}$

$= 6.6 \times 10^{-13}$

Our answer should have no more sig figs than any of our starting values

A subtle calculator error

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} =$$

$$6.615942028986 \times 10^{-13}$$

$$= \quad 6.6 \times 10^{-13}$$

WAIT!

Some of you may have experienced a subtle calculator error if you didn’t use the “EE” key!

Try this one now...

$$\frac{(8.30 \times 10^{-4})(5.5 \times 10^{-6})}{6.9 \times 10^{3}} =$$

Again, here's the button sequence I used:

8 . 3 0 2nd EE (-) 4 x 5 . 5 2nd EE (-) 6 ÷ 6 . 9 2nd EE 3

What is 2.3×10^{-3} written as a non-exponential number?

1. 0.0023
2. 2300
3. 23000
4. 0.023

What is 2.3×10^{-3} written as a non-exponential number?

1. 0.0023
2. 2300
3. 23000
4. 0.023

The negative exponent means we're dealing with a number less than 1.

What is 2.3 x 10^{-3} written as a non-exponential number?

1. 0.0023
2. ~~2300~~
3. ~~23000~~
4. 0.023

The negative exponent means we're dealing with a number less than 1.

What is 2.3×10^{-3} written as a non-exponential number?

1. 0.0023
2. ~~2300~~
3. ~~23000~~
4. 0.023

-3 means we've moved the decimal point three places to the right from where it originally was

What is 2.3×10^{-3} written as a non-exponential number?

1. 0.0023
2. ~~2300~~
3. ~~23000~~
4. 0.023

-3 means we've moved the decimal point three places to the right from where it originally was

0002.3

3 places

What is 2.3 x 10^{-3} written as a non-exponential number?

1. 0.0023
2. ~~2300~~
3. ~~23000~~
4. 0.023

-3 means we've moved the decimal point three places to the right from where it originally was

0.0023

3 places

What is 2.3 x 10^{-3} written as a non-exponential number?

1. 0.0023
2. ~~2300~~
3. ~~23000~~
4. ~~0.023~~

-3 means we've moved the decimal point three places to the right from where it originally was

0.0023

Express 56 100 000 000 in scientific notation

1. 5.61×10^{9}
2. 5.61×10^{-10}
3. 5.61×10^{10}
4. 5.61×10^{11}

Express 56 100 000 000 in scientific notation

1. 5.61×10^{9}
2. ~~5.61×10^{-10}~~
3. 5.61×10^{10}
4. 5.61×10^{11}

Our answer will have a positive exponent since the number is bigger than 1

Express 56 100 000 000 in scientific notation

1. 5.61×10^{9}
2. ~~5.61×10^{-10}~~
3. 5.61×10^{10}
4. 5.61×10^{11}

We need to move the decimal 10 places to position it between the first two non-zero digits

$$56\ \underbrace{100}_{9}\ \underbrace{000}_{6}\ \underbrace{000}_{3}$$

Express 56 100 000 000 in scientific notation

1. ~~5.61 x 10^{9}~~
2. ~~5.61 x 10^{-10}~~
3. 5.61 x 10^{10}
4. ~~5.61 x 10^{11}~~

We need to move the decimal 10 places to position it between the first two non-zero digits

56 100 000 000

9 6 3

How many sig figs?

- 0.00003500

How many sig figs?

- 0.00003500 4 decimal present
  ....toss leading zeros

How many sig figs?

- 0.00003500   4   decimal present
  ….toss leading zeros
- 6,700,300 000

How many sig figs?

- 0.00003500 4 decimal present
  ….toss leading zeros
- 6,700,300 000 5 no decimal present
  ….toss trailing zeros

How many sig figs?

- 0.00003500   4   decimal present
  ….toss leading zeros
- 6,700,300 000   5   no decimal present
  ….toss trailing zeros
- 327.000

How many sig figs?

- 0.00003500 4 decimal present
  …. toss leading zeros
- 6,700,300 000 5 no decimal present
  …. toss trailing zeros
- 327.000 6 decimal present
  no leading zeros

Calculate with sig figs…

$$\frac{4.2 \times 10^{3}}{(2 \times 10^{-6})(7.1 \times 10^{-3})} = ?$$

1. 3×10^{11}
2. 1.5×10^{7}
3. 1×10^{7}
4. 3.0×10^{11}

Calculate with sig figs…

$$\frac{4.2 \times 10^{3}}{(2 \times 10^{-6})(7.1 \times 10^{-3})} = ?$$

1. $\boxed{3 \times 10^{11}}$
2. 1.5×10^{7}
3. 1×10^{7}
4. 3.0×10^{11}

Calculate with sig figs…

$$\frac{\overset{\boxed{2\text{ s.f.}}}{4.2} \times 10^{3}}{(\underset{\boxed{1\text{ s.f.}}}{2} \times 10^{-6})(\underset{\boxed{2\text{ s.f.}}}{7.1} \times 10^{-3})} = \ ?$$

The calculator sees it as:

(4.2E3) ÷ (2E–6) ÷ (7.1E– 3) =

$2.957746479 \times 10^{11}$

How many sig figs?

Calculate with sig figs…

2 s.f.

$$\frac{\mathbf{4.2 \times 10^{3}}}{(\mathbf{2 \times 10^{-6}})(\mathbf{7.1 \times 10^{-3}})} = \ ?$$

1 s.f. 2 s.f.

The calculator sees it as:

(4.2E3) ÷ (2E–6) ÷ (7.1E– 3) =

$2.957746479 \times 10^{11}$

How many sig figs? We only get 1 s.f.!

Calculate with sig figs…

$$\frac{\overset{\boxed{2\text{ s.f.}}}{\mathbf{4.2 \times 10^{3}}}}{(\underset{\boxed{1\text{ s.f.}}}{\mathbf{2}} \mathbf{\times 10^{-6}})(\underset{\boxed{2\text{ s.f.}}}{\mathbf{7.1}} \mathbf{\times 10^{-3}})} = 3 \times 10^{11}$$

The calculator sees it as:

(4.2E3) ÷ (2E–6) ÷ (7.1E– 3) =

$2.957746479 \times 10^{11}$

How many sig figs? We only get 1 s.f.!

Measurements

- Measurements consist of two parts…
- A number
- The associated units

Consider a distance of 872

- 872 miles
- 872 light years
- 872 nanometers
- 872 smoots

Unit Systems

- Metric
- *Systeme International d'Unites* (SI)
- English

Unit Systems

- Metric
- *Systeme International d'Unites* (SI)
- English
- Only still in use in US, Liberia and Burma
- Although many metric units used in US, e.g., mg in doses of medicine and L for large soda bottles

Basic metric system

- Length in meters (m)
- Volume in cubic meters (m^3) or liters (L) or cm^3 (cc's)
- Mass in grams (g)
- Time in seconds (s)

Unit prefixes

Unit prefixes

Units often turn out to be inconveniently large or small.

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

(5.50×10^{-7} m)

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

milli

(5.50×10^{-7} m)

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

milli micro

(5.50 x 10^{-7} m)

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

000	000	550
milli	micro	nano

(5.50×10^{-7} m)

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

milli micro nano

(5.50×10^{-7} m)

Nicer to say

550 nanometers (nm)

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

milli micro nano

(5.50×10^{-7} m)

thousandths

millionths

billionths

Nicer to say

550 nanometers (nm)

Unit prefixes

Units often turn out to be inconveniently large or small.

Green light is 0. 000 000 550 m

milli micro nano

(5.50×10^{-7} m)

thousandths

millionths

billionths

Nicer to say

550 nanometers (nm)

550 billionths of a meter

Unit prefixes to learn...

giga- (G)	10^{9}	1 Gg = 10^{9} g	billions
mega- (M)	10^{6}	1 Mg = 10^{6} g	millions
kilo- (k)	10^{3}	1 kg = 10^{3} g	thousands
deci- (d)	10^{-1}	1 dg = 10^{-1} g	tenths
centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12}g	trillionths

Unit prefixes to learn...

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micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12} g	trillionths

I've placed a 1 in front of each prefixed unit in this table

Unit prefixes to learn...

giga- (G)	10^{9}	Gee!	billions
mega- (M)	10^{6}	Megan	millions
kilo- (k)	10^{3}	killed	thousands
deci- (d)	10^{-1}	Desi's	tenths
centi- (c)	10^{-2}	scent.	hundredths
milli- (m)	10^{-3}	Millie	thousandths
micro- (μ)	10^{-6}	microwaved	millionths
nano- (n)	10^{-9}	Nan's	billionths
pico- (p)	10^{-12}	Piccolo.	trillionths

Here's two nonsense phrases to help you remember these prefixes in order

Unit prefixes to learn...

giga- (G)	10^9	1 Gg = 10^9 g	billions
mega- (M)	10^6	1 Mg = 10^6 g	millions
kilo- (k)	10^3	1 kg = 10^3 g	thousands
deci- (d)	10^{-1}	1 dg = 10^{-1} g	tenths
centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12} g	trillionths

How many microliters (μL) are there in 3.27×10^{-5} L?

1. 0.0327 μL
2. 3.27 μL
3. 32.7 μL
4. 327 μL

Unit prefixes to learn...

giga- (G)	10^9	1 Gg = 10^9 g	billions
mega- (M)	10^6	1 Mg = 10^6 g	millions
kilo- (k)	10^3	1 kg = 10^3 g	thousands
deci- (d)	10^{-1}	1 dg = 10^{-1} g	tenths
centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12}g	trillionths

Find the best prefix by looking for an exponent equal to or smaller than your value. We have 3.27×10^{-5}, so

Unit prefixes to learn...

giga- (G)	10^9	1 Gg = 10^9 g	billions
mega- (M)	10^6	1 Mg = 10^6 g	millions
kilo- (k)	10^3	1 kg = 10^3 g	thousands
deci- (d)	10^{-1}	1 dg = 10^{-1} g	tenths
centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12}g	trillionths

Find the best prefix by looking for an exponent equal to or smaller than your value. We have 3.27 x 10^{-5}, so

Unit prefixes to learn...

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deci- (d)	10^{-1}	1 dg = 10^{-1} g	tenths
centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12}g	trillionths

Values that have an exponent of 10^{-6} or 10^{-5} or 10^{-4} can be nicely expressed using the prefix micro

Unit prefixes to learn...

giga- (G)	10^{9}	1 Gg = 10^{9} g	billions
mega- (M)	10^{6}	1 Mg = 10^{6} g	millions
kilo- (k)	10^{3}	1 kg = 10^{3} g	thousands
deci- (d)	10^{-1}	1 dg = 10^{-1} g	tenths
centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
nano- (n)	10^{-9}	1 ng = 10^{-9} g	billionths
pico- (p)	10^{-12}	1 pg = 10^{-12} g	trillionths

$10^{-6} = 1 – 9$

$10^{-5} = 10 – 99 \longleftarrow 3.27 \times 10^{-5}$

$10^{-4} = 100 – 999$

How many microliters (μL) are there in 3.27×10^{-5} L?

1. 0.0327 μL
2. 3.27 μL
3. 32.7 μL
4. 327 μL

How many microliters (μL) are there in 3.27 x 10^{-5} L?

1. 0.0327 μL
2. 3.27 μL
3. $\boxed{32.7\ \mu L}$
4. 327 μL

How many microliters (μL) are there in 3.27×10^{-5} L?

How many microliters (μL) are there in 3.27×10^{-5} L?

- Written in non-exponential form this is
- 0. 000   032 7   L

How many microliters (μL) are there in 3.27×10^{-5} L?

- Written in non-exponential form this is
- 0. 000 032 7 L

milli

How many microliters (μL) are there in 3.27×10^{-5} L?

- Written in non-exponential form this is
- 0. $\boxed{000}$ $\boxed{032}$ 7 L

milli micro

How many microliters (μL) are there in 3.27×10^{-5} L?

- Written in non-exponential form this is
- 0. $\boxed{000}$ $\boxed{032}$ 7 L

milli micro

Answer: 32.7 μL

Unit prefixes to learn...

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mega- (M)	10^6	1 Mg = 10^6 g	millions
kilo- (k)	10^3	1 kg = 10^3 g	thousands
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centi- (c)	10^{-2}	1 cg = 10^{-2} g	hundredths
milli- (m)	10^{-3}	1 mg = 10^{-3} g	thousandths
micro- (μ)	10^{-6}	1 μg = 10^{-6} g	millionths
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How many microliters (μL) are there in 3.27×10^{-5} L?

- Written in non-exponential form this is
- 0. 000 032 7 L

milli micro

32.7 millionths

Answer: 32.7 μL

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

Just replace the "m" for "milli-" with the exponent from the prefix table

350 mg

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

Just replace the "m" for "milli-" with the exponent from the prefix table

350 mg

milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

Just replace the "m" for "milli-" with the exponent from the prefix table

350×10^{-3} g

milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

Now enter this number in your calculator using the proper keystrokes…
3 5 0 “EE” (-) 3

350×10^{-3} g

milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

Now enter this number in your calculator using the proper keystrokes…
3 5 0 “EE” (-) 3

3.50×10^{-1} g
milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. $\boxed{3.50 \times 10^{-1}\ g}$
4. 350×10^{-3} g

Now enter this number in your calculator using the proper keystrokes…
3 5 0 “EE” (-) 3

3.50×10^{-1} g
milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. $\boxed{0.350 \text{ g}}$
2. 3.50 g
3. $\boxed{3.50 \times 10^{-1} \text{ g}}$
4. 350×10^{-3} g

This is an equivalent answer!

3.50×10^{-1} g

milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

This is an equivalent answer!

As is this!

3.50×10^{-1} g

milli- means 10^{-3}

How many grams are in 350 milligrams (mg)?

1. 0.350 g
2. 3.50 g
3. 3.50×10^{-1} g
4. 350×10^{-3} g

Floating or fixed point decimal notation

Scientific notation

Engineering notation

3.50×10^{-1} g

milli- means 10^{-3}

Temperature Systems

- Metric: Celsius (or centigrade)
- SI: Kelvin
- English: Fahrenheit

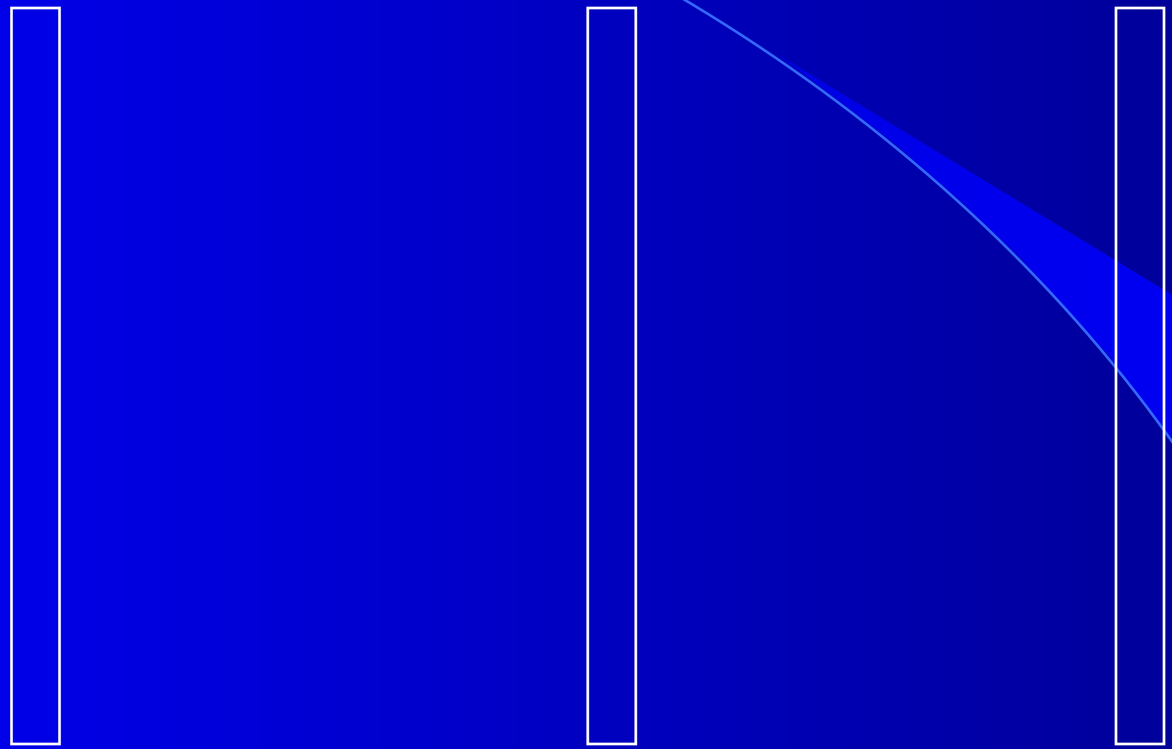
Celsius *vs.* Kelvin

- Both scales have the same size of degree
- 100 steps between freezing point and boiling point of water
- Celsius goes from 0 to 100
- Kelvin goes from 273 to 373

Fahrenheit Scale

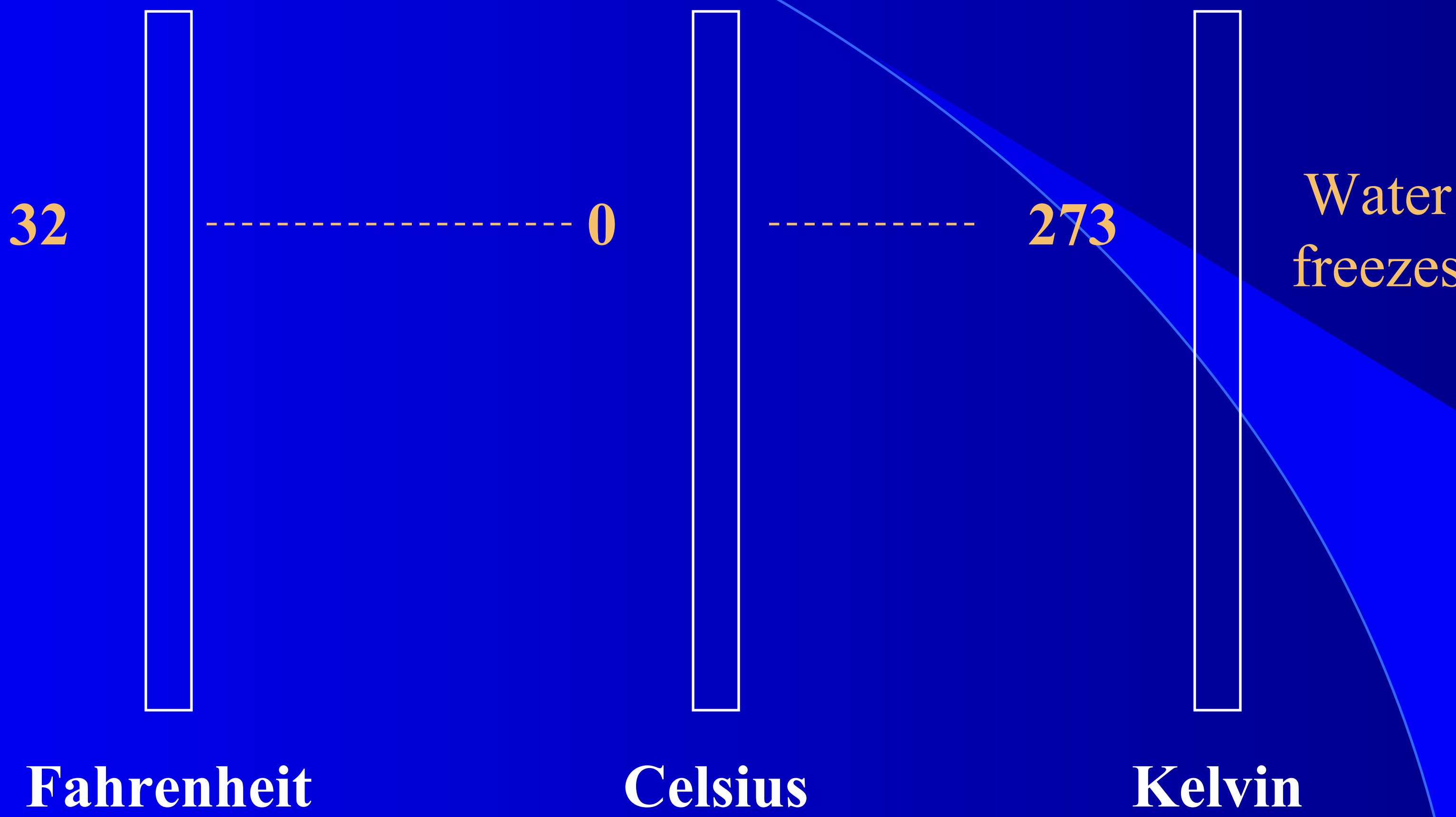
- Has 180 steps between freezing and boiling points of water
  - 1° Celsius = 1.8° Fahrenheit
- The scales also differ in their starting points
  - 32 °F = 0 °C

Temperature Scales

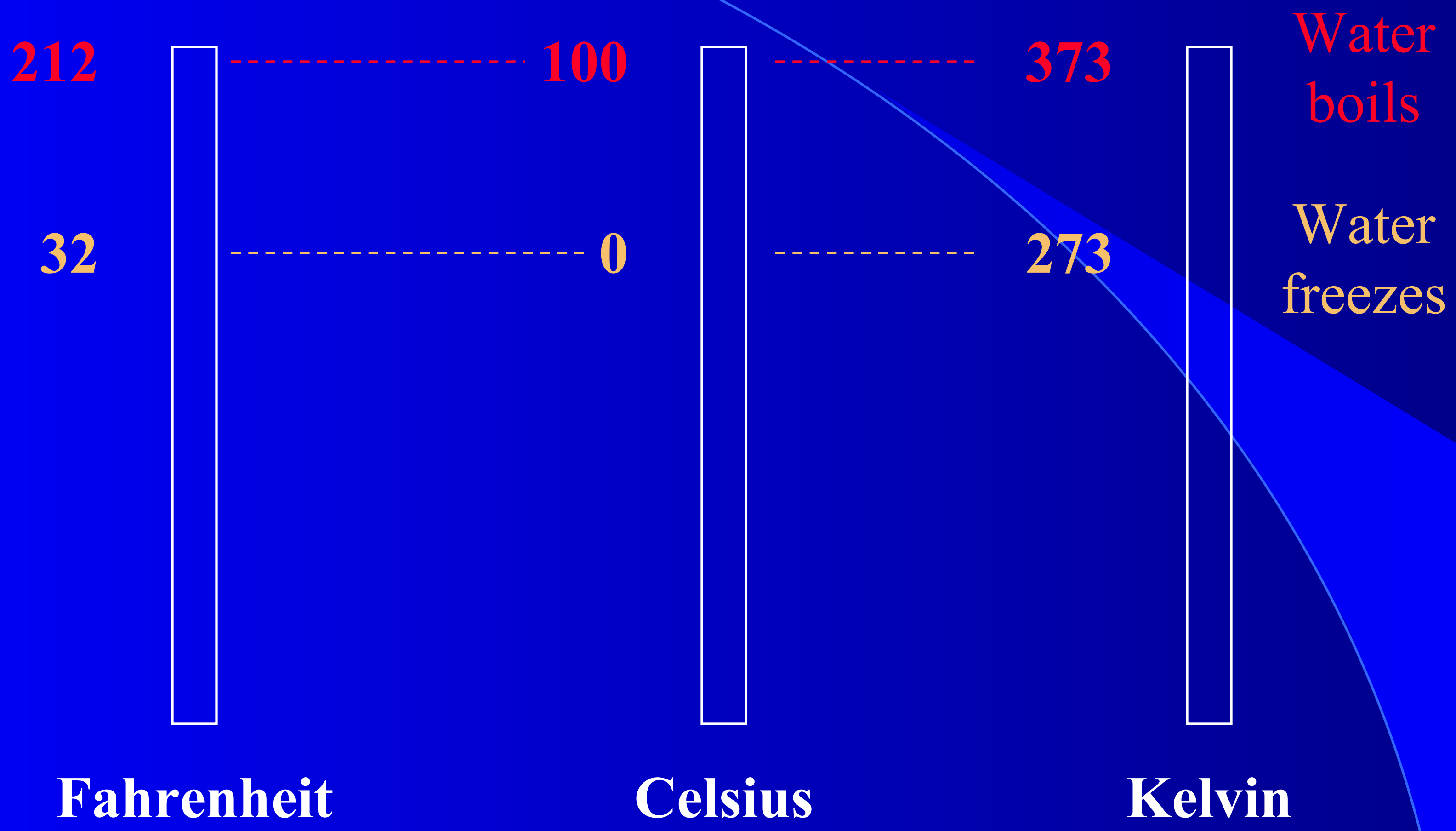


Fahrenheit **Celsius** **Kelvin**

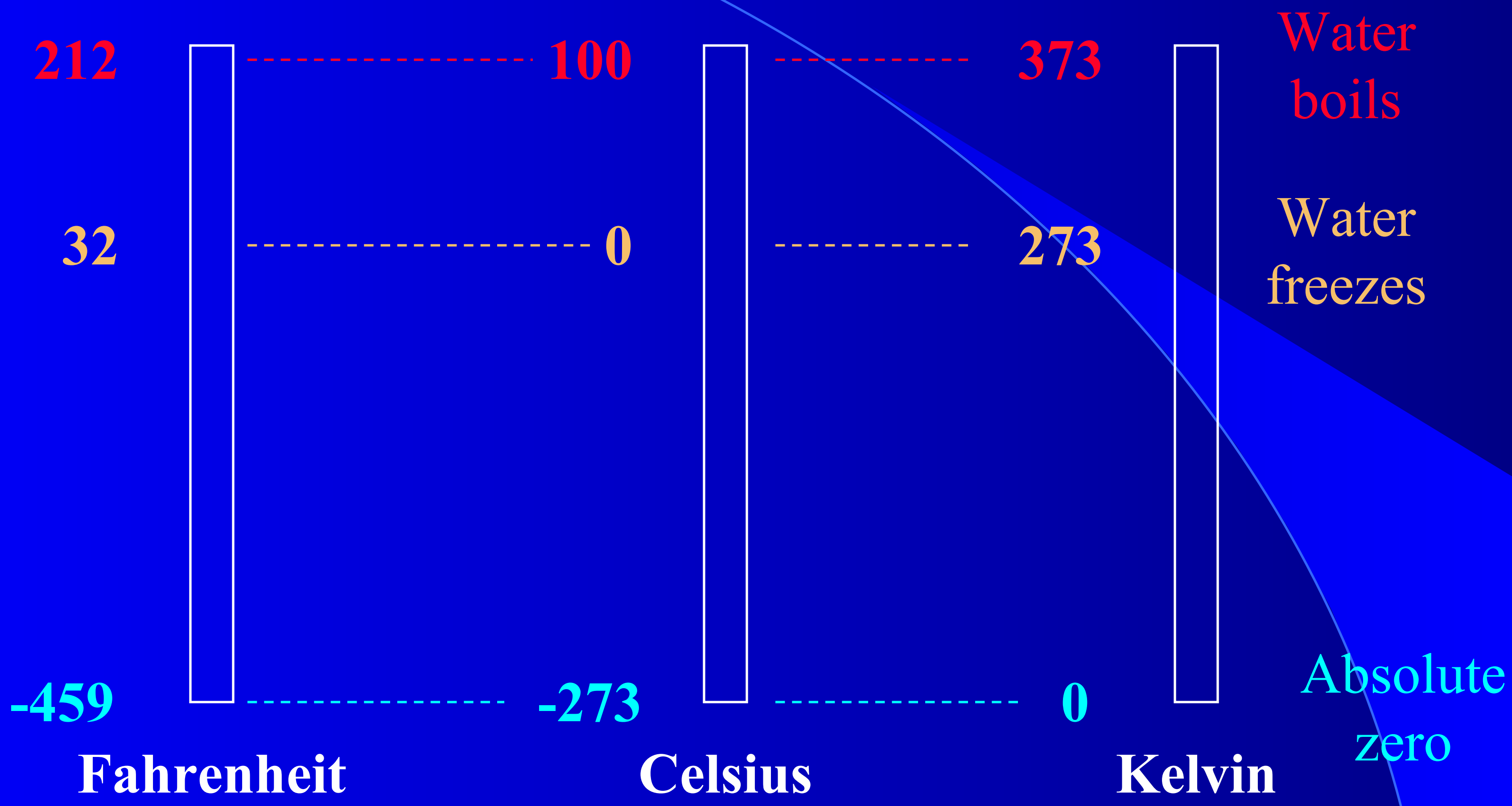
Freezing Point of Water



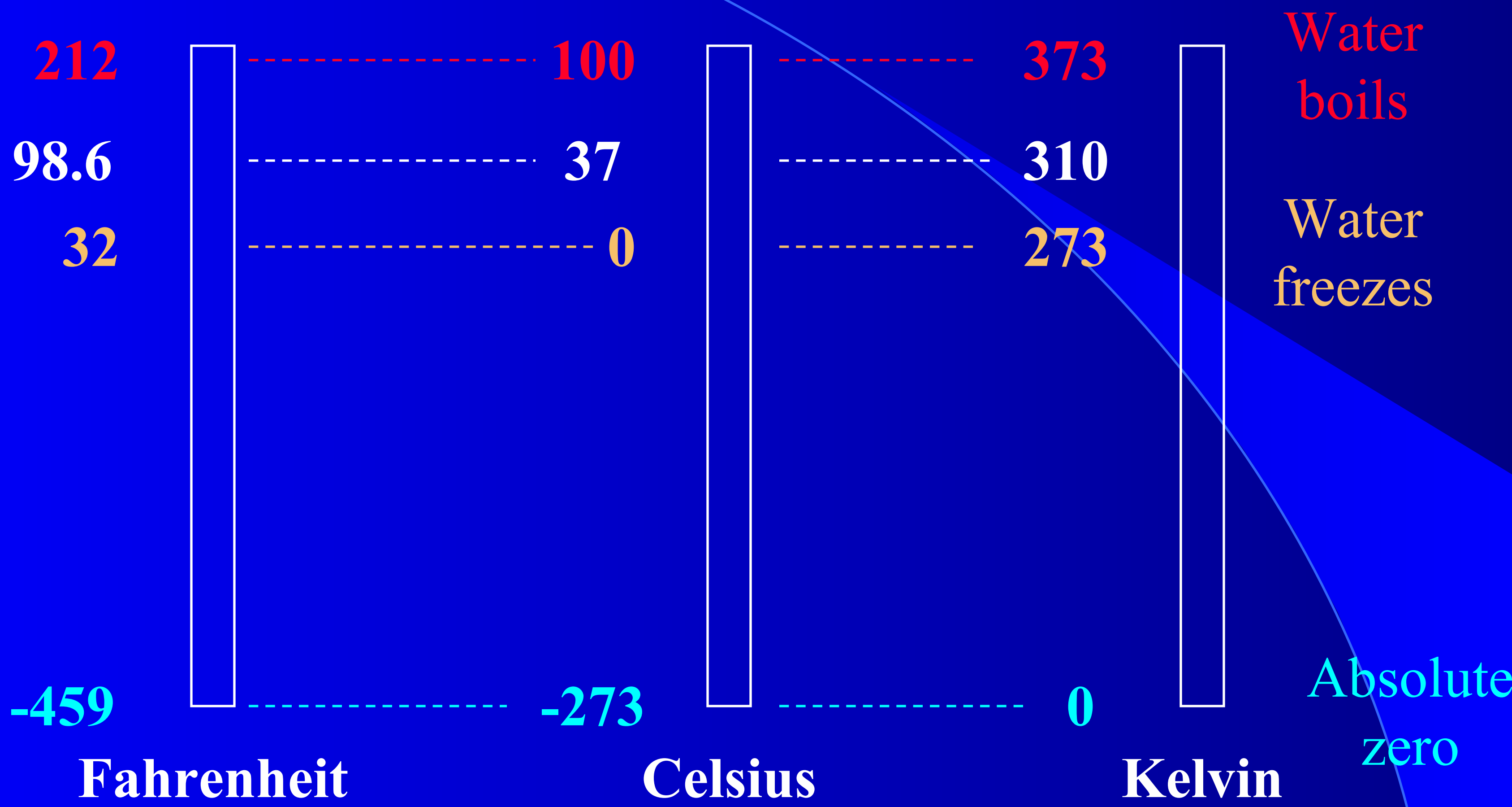
Boiling Point of Water



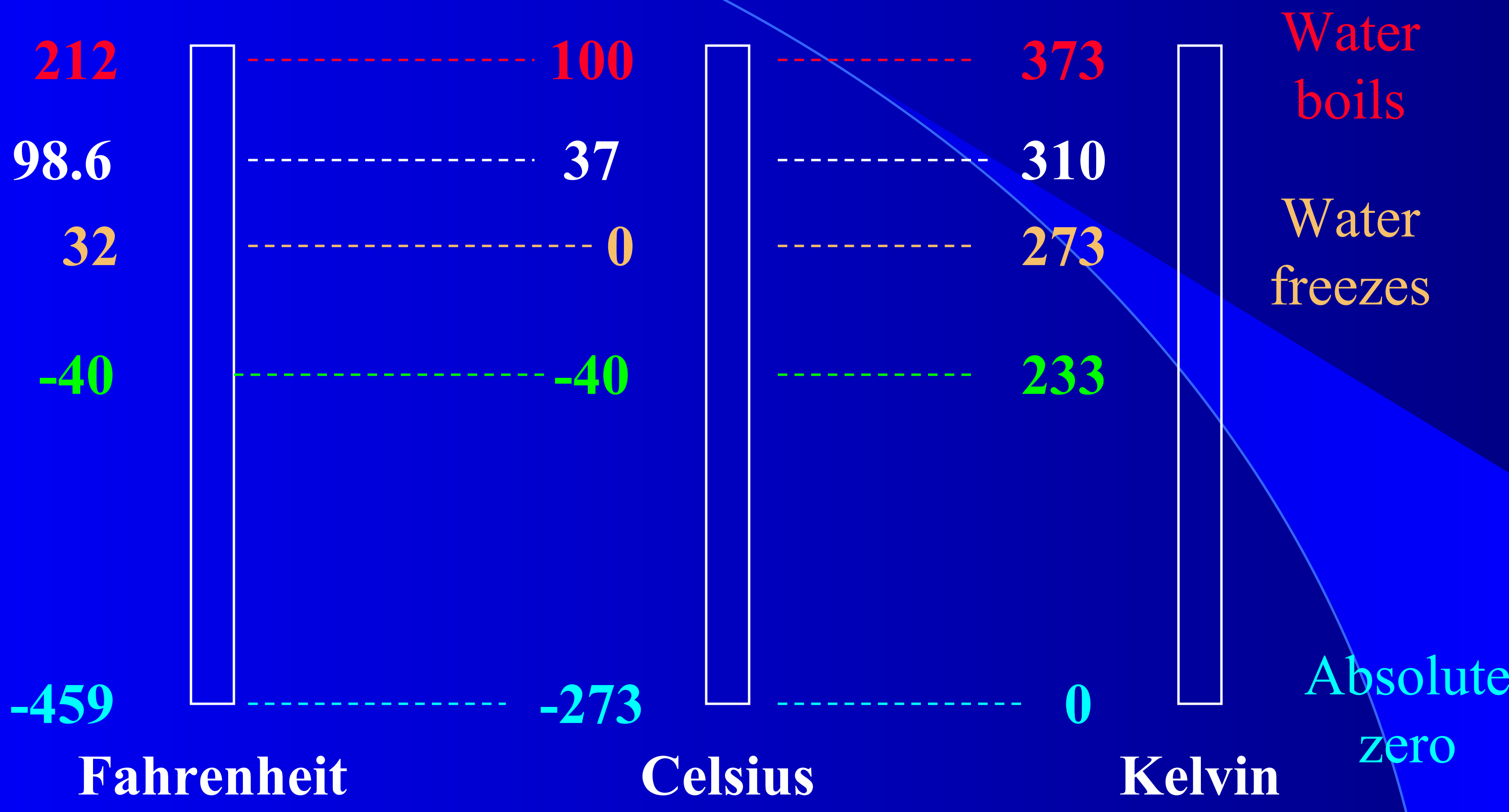
Absolute Zero



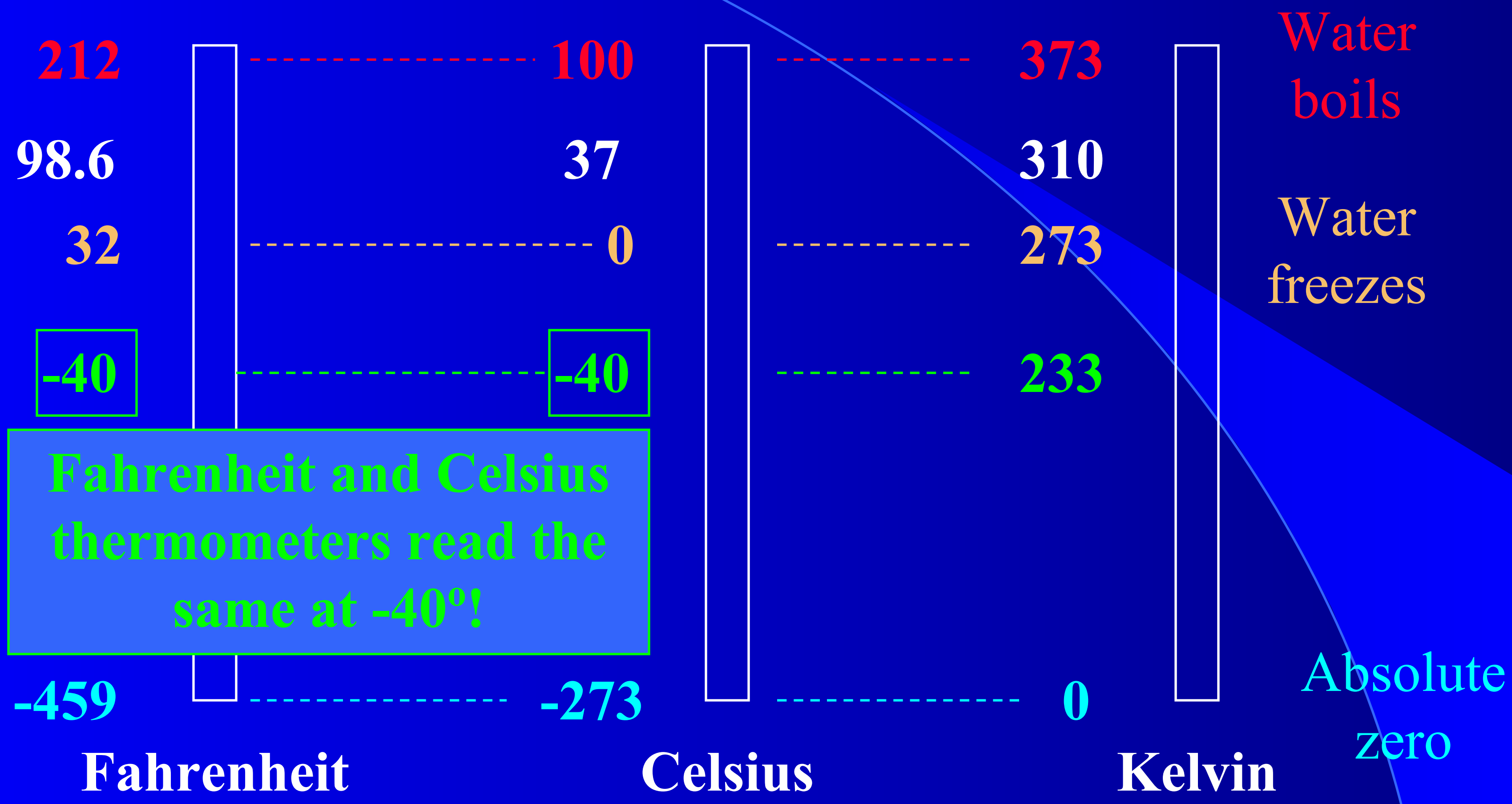
Body Temperature



Crossover Point



Crossover Point



Celsius/Kelvin Conversions

- $K = {}^{o}C + 273$
- ${}^{o}C = K - 273$

If the temperature outside is 263 K, what season is it? (Calculate the equivalent ºC)

1. Summer
2. Fall
3. Winter
4. Spring

If the temperature outside is 263 K, what season is it? (Calculate the equivalent ^oC)

$$^oC = K - 273$$

1. Summer
2. Fall
3. Winter
4. Spring

We'll use the "^oC =" form since we want our answer in ^oC.

If the temperature outside is 263 K, what season is it? (Calculate the equivalent ºC)

$$°C = K - 273$$

$$°C = 263 - 273$$

1. Summer
2. Fall
3. Winter
4. Spring

If the temperature outside is 263 K, what season is it? (Calculate the equivalent ºC)

1. Summer
2. Fall
3. Winter
4. Spring

$$^{o}C = K - 273$$

$$^{o}C = 263 - 273$$

If the temperature outside is 263 K, what season is it? (Calculate the equivalent ºC)

1. Summer
2. Fall
3. Winter
4. Spring

ºC = K - 273

ºC = 263 - 273

ºC = - 10 (Brr! It feels like winter!)

If the temperature outside is 263 K, what season is it? (Calculate the equivalent ºC)

1. Summer
2. Fall
3. $\boxed{\text{Winter}}$
4. Spring

$$^{\circ}C = K - 273$$

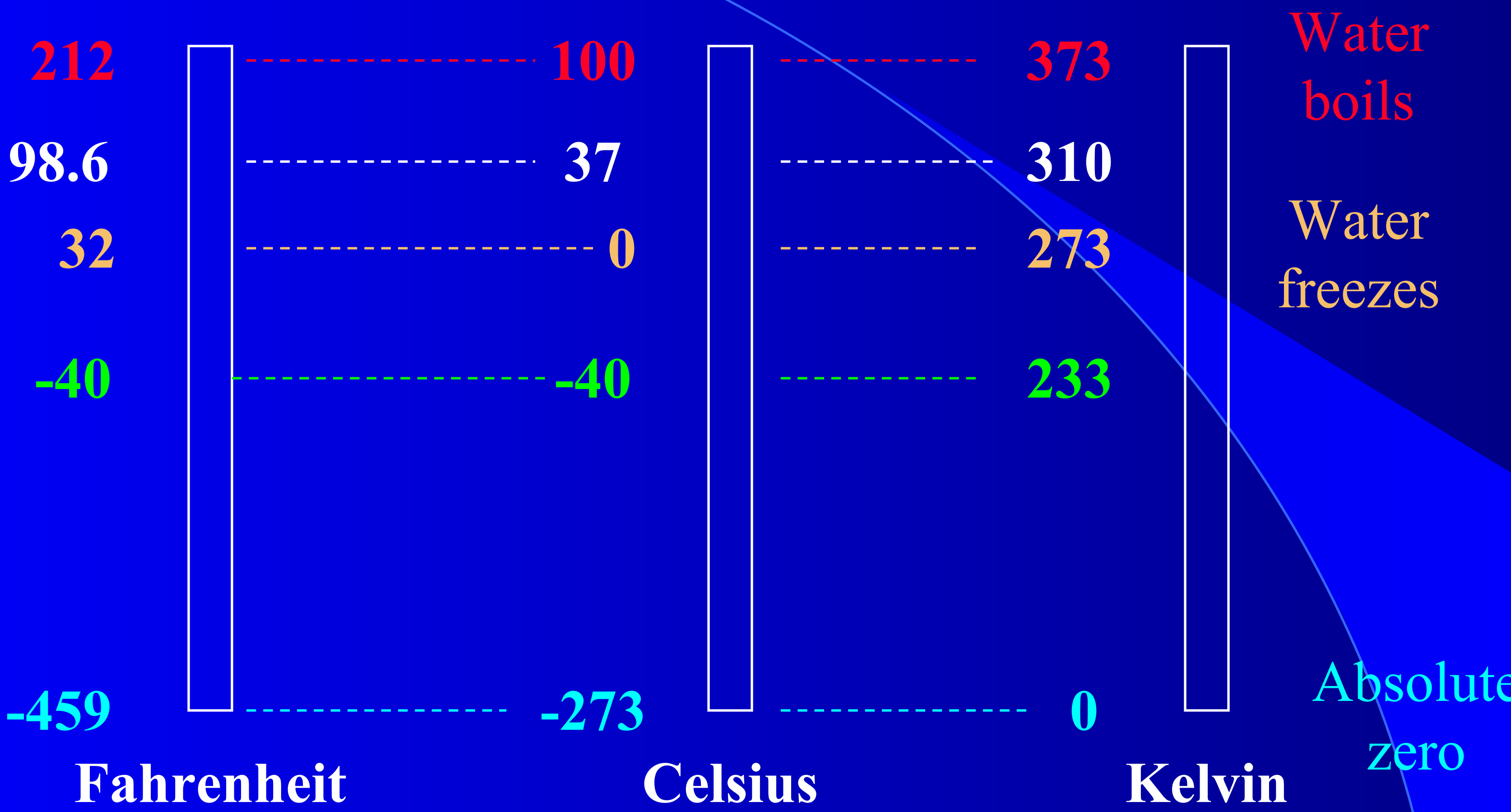
$$^{\circ}C = 263 - 273$$

$$^{\circ}C = -10$$ (Brr! It feels like winter!)

Fahrenheit Scale

- Has 180 steps between freezing and boiling points of water
  - 1^{o} Celsius $= 1.8^{o}$ Fahrenheit
- The scales also differ in their starting points
  - $32\ ^{o}F = 0\ ^{o}C$

Crossover Point



Celsius/Fahrenheit Conversions

$$^{o}F = (1.8 \times {}^{o}C) + 32$$

Celsius/Fahrenheit Conversions

$$^{o}F = (1.8 \times {}^{o}C) + 32$$

$$^{o}C = \frac{({}^{o}F - 32)}{1.8}$$

Celsius/Fahrenheit Conversions

$$^{o}F = (1.8 \times {}^{o}C) + 32$$

$$^{o}C = \frac{({}^{o}F - 32)}{1.8}$$

Here's the adjustment for the difference in degree size (180 steps vs. 100 steps)

Some books use 9/5 or 5/9 instead of the 1.8

Celsius/Fahrenheit Conversions

$$^{o}F = (1.8 \times {}^{o}C) + 32$$

Here's the zero point offset adjustment

$$^{o}C = \frac{(^{o}F - 32)}{1.8}$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ^{o}F.

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ^{o}F.
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$$^{o}C = \frac{(^{o}F - 32)}{1.8}$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$\boxed{{}^{o}C} = \frac{({}^{o}F - 32)}{1.8}$$

We use this form because we want our answer in ºC

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{o}C = \frac{(^{o}F - 32)}{1.8}$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{o}C = \frac{(-3 \ - \ 32)}{1.8}$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{o}C = \frac{(-3 - 32)}{1.8}$$

Need parens here to force subtraction before division

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ^oF.
- What is the equivalent temperature on the Celsius scale?

$$^oC = \frac{(-3 - 32)}{1.8}$$

Need parens here to force subtraction before division

Keystroke sequence is:

((-) 3 - 3 2) ÷ 1 . 8

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{\circ}C = \frac{(-3 - 32)}{1.8} = \frac{-35}{1.8}$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{\circ}C = \frac{(-3 - 32)}{1.8} = \frac{-35}{1.8}$$

$$= -19.4444444\ ^{\circ}C$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

In subtracting, sig fig rules say retain the fewest decimal places

$$^{o}C = \frac{(-3 \ - \ 32)}{1.8} = \frac{-35}{1.8}$$

$$= -19.4444444\ ^{o}C$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

Both the 3 and the 32 are good to ±1 degree, so answer is too.

$$^{o}C = \frac{(-3 - 32)}{1.8} = \frac{-35}{1.8}$$

$$= -19.4444444\ ^{o}C$$

A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{\circ}\mathrm{C} = \frac{(-3 - 32)}{1.8} = \frac{\overset{\boxed{2\ \text{s.f.}}}{-35}}{1.8}\ \boxed{2\ \text{s.f.}}$$

$$= -19.4444444\ ^{\circ}\mathrm{C}$$

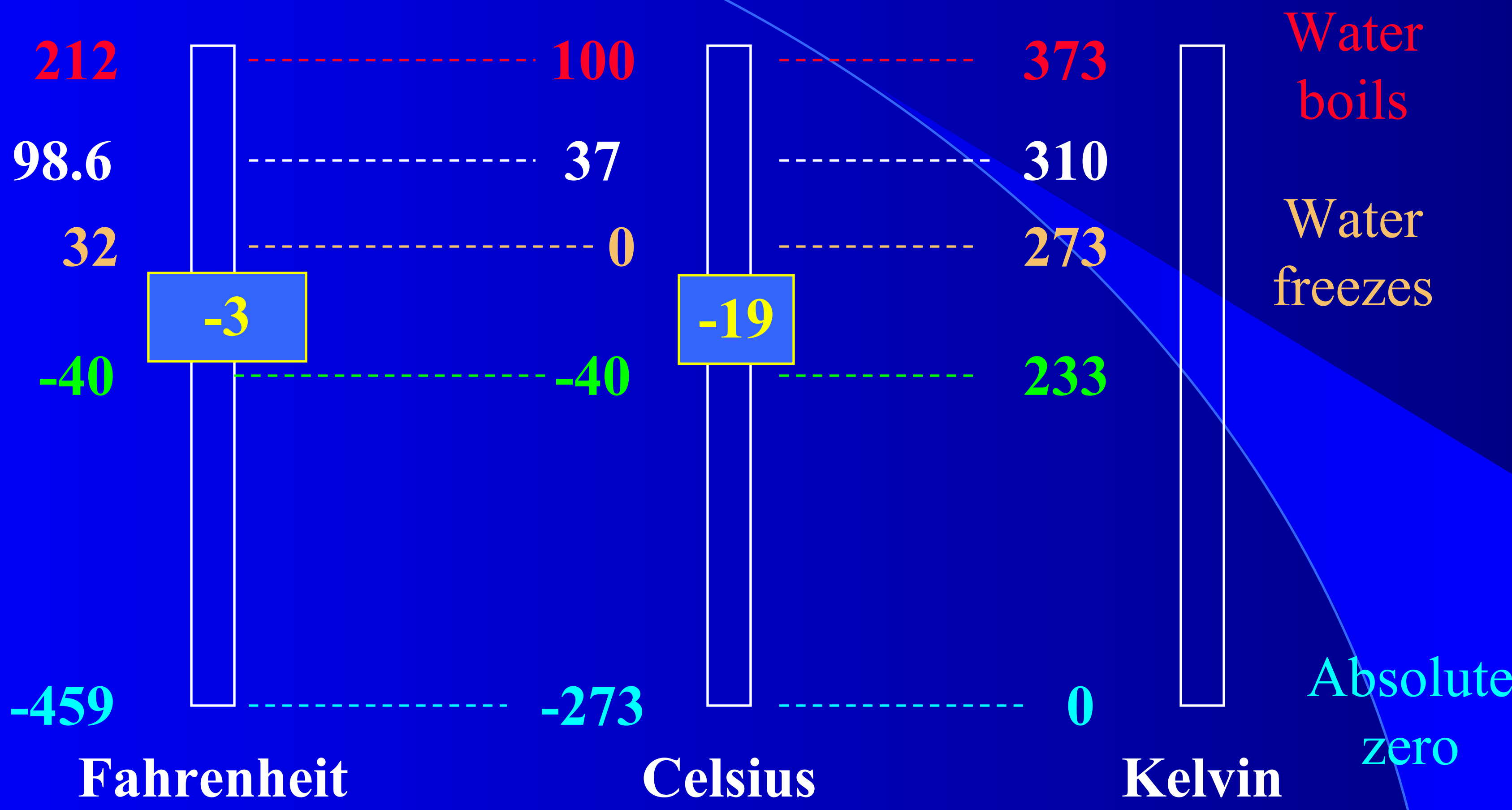
A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{\circ}\mathrm{C} = \frac{(\overbrace{-3}^{}\ -\ 32)}{1.8} = \frac{\overset{\boxed{2\text{ s.f.}}}{-35}}{\underset{\boxed{2\text{ s.f.}}}{1.8}}$$

$$= -19.4444444\ ^{\circ}\mathrm{C} = \underset{\boxed{2\text{ s.f.}}}{-19}\ ^{\circ}\mathrm{C}$$

Check your answer...



A Sample Calculation…..

- On January 23rd, 2008 the overnight low temperature at the Missoula International airport was -3 ºF.
- What is the equivalent temperature on the Celsius scale?

$$^{o}C = \frac{(-3 - 32)}{1.8} = \frac{-35}{1.8}$$

$$= -19.4444444\ ^{o}C = -19\ ^{o}C$$

You get -20.8 ºC if you forget to include parens!

If the temperature is 16ºC, what is this in ºF?

1. -8.9 ºF
2. 86.4 ºF
3. 60.8
4. 61

If the temperature is 16ºC, what is this in ºF?

$$°F = (1.8 \times °C) + 32$$

1. -8.9 ºF
2. 86.4 ºF
3. 60.8
4. 61

If the temperature is 16°C, what is this in °F?

1. -8.9 °F
2. 86.4 °F
3. 60.8
4. 61

$$°F = (1.8 \times °C) + 32$$

$$°F = (1.8 \times 16) + 32$$

If the temperature is 16ºC, what is this in ºF?

1. -8.9 ºF
2. 86.4 ºF
3. 60.8
4. 61

$$^{o}F = (1.8 \times {}^{o}C) + 32$$

$$^{o}F = (1.8 \times 16) + 32$$

$$^{o}F = (28.8) + 32$$

If the temperature is 16ºC, what is this in ºF?

1. -8.9 ºF
2. 86.4 ºF
3. 60.8
4. 61

$$ºF = (1.8 \times ºC) + 32$$

$$ºF = (1.8 \times 16) + 32$$

$$ºF = (28.8) + 32$$

$$ºF = 60.8$$

If the temperature is 16ºC, what is this in ºF?

1. -8.9 ºF
2. 86.4 ºF
3. 60.8
4. 61

$$°F = (1.8 \times °C) + 32$$

$$°F = (1.8 \times 16) + 32$$

$$°F = (28.8) + 32$$

$$°F = 60.8$$

$$°F = 61$$

(with sig figs – 28.8 should be rounded up to 29)

If the temperature is 16ºC, what is this in ºF?

1. -8.9 ºF
2. 86.4 ºF
3. 60.8
4. 61

$$^{o}F = (1.8 \times {}^{o}C) + 32$$

$$^{o}F = (1.8 \times 16) + 32$$

$$^{o}F = (28.8) + 32$$

$$^{o}F = 60.8$$

$$^{o}F = 61$$

Unit Conversions

- Lab, clinic or field situations often require information in a form different from the way it's supplied
- How many grams of a chemical are needed to make the right solution concentration?
- How many cc's of medication (based on a patient's weight) is the proper dose?
- How much of a toxic substance will be passed up the food-chain if an osprey eats a contaminated fish?

The Factor-Label Method

- Uses conversion factors to go between unit systems

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Starting quantity **x**

The Factor-Label Method

- Uses conversion factors to go between unit systems

Starting quantity	**x**	**Conversion factor(s)**

The Factor-Label Method

- Uses conversion factors to go between unit systems

Starting quantity x Conversion factor(s) = Equivalent quantity

Conversion Factors

- In use, a conversion factor will appear as a fraction

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$$\frac{\mathbf{1.609\ km}}{\mathbf{1.000\ mile}}$$

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$$\frac{\mathbf{1.609\ km}}{\mathbf{1.000\ mile}} \quad \text{or} \quad \frac{\mathbf{1.000\ mile}}{\mathbf{1.609\ km}}$$

Conversion Factors

- In use, a conversion factor will appear as a fraction

$$\frac{\mathbf{1.609\ km}}{\mathbf{1.000\ mile}} \quad \text{or} \quad \frac{\mathbf{1.000\ mile}}{\mathbf{1.609\ km}}$$

- The orientation depends on which one makes units cancel

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).
- It commemorates the legendary feat of Pheidippides who ran from Marathon to Athens in 490 B.C.E. to announce the Greek victory over the Persians.

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

Starting quantity

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

26.22 miles

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

26.22 miles

Units of answer

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

26.22 miles $\longrightarrow$ km

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

26.22 miles km

Now acquire a conversion factor that relates miles and km

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

26.22 miles km

Arrange it so that miles are on the bottom and will cancel out

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\text{ miles} \qquad \frac{1.609\text{ km}}{1.000\text{ mile}} \qquad\qquad \text{km}$$

Arrange it so that miles are on the bottom and will cancel out

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22 \text{ miles} \times \frac{1.609 \text{ km}}{1.000 \text{ mile}} \qquad\qquad \text{km}$$

Miles will cancel out

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} \qquad\qquad \text{km}$$

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} \qquad \text{km}$$

Remaining units are same as answer units

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} \qquad\qquad \text{km}$$

Now do the math

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} \qquad\qquad \text{km}$$

$$\boxed{\frac{26.22 \times 1.609}{1.000}}$$

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22 \cancel{\text{ miles}} \times \frac{1.609\text{ km}}{1.000 \cancel{\text{ mile}}} \qquad \text{km}$$

$$\boxed{\frac{26.22 \times 1.609}{1.000}}$$

The 1.000 drops out

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22 \cancel{\text{ miles}} \times \frac{1.609 \text{ km}}{1.000 \cancel{\text{ mile}}} \qquad \text{km}$$

$\boxed{26.22 \times 1.609}$

Now multiply

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22 \cancel{\text{miles}} \times \frac{1.609 \text{ km}}{1.000 \cancel{\text{mile}}} \qquad \text{km}$$

$$\boxed{42.187980}$$

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} \qquad \text{km}$$

$$\boxed{42.187980}$$

Round to correct sig figs

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$\underset{\text{4 s.f.}}{26.22\ \cancel{\text{miles}}} \times \frac{\overset{\text{4 s.f.}}{1.609\ \text{km}}}{\underset{\text{4 s.f.}}{1.000\ \cancel{\text{mile}}}} \qquad \text{km}$$

$$\boxed{42.187980}$$

Round to correct sig figs

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$\underset{4\text{ s.f.}}{26.22\ \cancel{\text{miles}}} \times \frac{\overset{4\text{ s.f.}}{1.609\text{ km}}}{\underset{4\text{ s.f.}}{1.000\ \cancel{\text{mile}}}} \qquad \text{km}$$

$$\boxed{42.187980}$$

Drop uncertain digits with rounding

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

4 s.f.

$$26.22 \cancel{\text{ miles}} \times \frac{1.609 \text{ km}}{1.000 \cancel{\text{ mile}}} \qquad \text{km}$$

4 s.f.

4 s.f.

$\boxed{42.19}$

Drop uncertain digits with rounding

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} = 42.19\ \text{km}$$

Sample calculation...

- In the Olympics, how long is the marathon event in kilometers? I know it's 26.22 miles long (26 miles 385 yds).

$$26.22\ \cancel{\text{miles}} \times \frac{1.609\ \text{km}}{1.000\ \cancel{\text{mile}}} = 42.19\ \text{km}$$

Starting quantity x Conversion factor(s) = Equivalent quantity

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

Another calculation...

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- How many micrograms in 4.5×10^{-5} g?

4.5×10^{-5} g

Starting value

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

4.5×10^{-5} g $\longrightarrow$ μg

Starting value **Answer units**

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

4.5×10^{-5} g μg

Starting value

Answer units

Obtain conversion factor

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5 x 10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} \qquad \mu g$$

Orient so that units cancel

Unit prefixes to learn...

giga- (G)	10^9	1 Gg = 10^9 g
mega- (M)	10^6	1 Mg = 10^6 g
kilo- (k)	10^3	1 kg = 10^3 g
deci- (d)	10^{-1}	1 dg = 10^{-1} g
centi- (c)	10^{-2}	1 cg = 10^{-2} g
milli- (m)	10^{-3}	1 mg = 10^{-3} g
micro- (μ)	10^{-6}	1 μg = 10^{-6} g
nano- (n)	10^{-9}	1 ng = 10^{-9} g
pico- (p)	10^{-12}	1 pg = 10^{-12} g

Unit prefixes to learn...

giga-	(G)	10^9	1 Gg = 10^9 g
mega-	(M)	10^6	1 Mg = 10^6 g
kilo-	(k)	10^3	1 kg = 10^3 g
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nano-	(n)	10^{-9}	1 ng = 10^{-9} g
pico-	(p)	10^{-12}	1 pg = 10^{-12}g

Aha! Here’s what we want.

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} \qquad \mu g$$

Orient so that units cancel

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = \qquad \mu g$$

Do the math

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = \qquad \mu g$$

$$\boxed{\frac{\mathbf{4.5 \times 10^{-5}}}{\mathbf{1.0 \times 10^{-6}}}}$$

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = \quad \mu g$$

Here's what you may need on your calculator for 10^{-6}

$$\boxed{\frac{\mathbf{4.5 \times 10^{-5}}}{\mathbf{1.0 \times 10^{-6}}}}$$

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = \boxed{45}\ \mu g$$

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5 x 10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = 45\ \mu g$$

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = 45\ \mu g$$

The answer makes sense when viewed like this...

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = 45\ \mu g$$

0.000 045 g

The answer makes sense when viewed like this...

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = 45\ \mu g$$

The answer makes sense when viewed like this...

$0.\boxed{000}\,045$ g

milli

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = 45\ \mu g$$

The answer makes sense when viewed like this...

$$0.\boxed{000}\,\boxed{045}\ g$$

milli micro

Another calculation...

- This example shows how to use the metric prefix table…
- How many micrograms in 4.5×10^{-5} g?

$$4.5 \times 10^{-5}\ \cancel{g} \times \frac{1.0\ \mu g}{10^{-6}\ \cancel{g}} = 45\ \mu g$$

The answer makes sense when viewed like this...

$$0.\underbrace{000}_{\text{milli}}\underbrace{045}_{\text{micro}}\ g$$

The Factor-Label Method

- A 31.7-kg dog needs valium to suppress hysteria from 4th of July fireworks. The prepared solution needs to be administered at the rate of 2.3 mL/kg. How many mL of valium solution should be injected?

Starting quantity **x** **Conversion factor(s)** **=** **Equivalent quantity**

The Factor-Label Method

- A 31.7-kg dog needs valium to suppress hysteria from 4th of July fireworks. The prepared solution needs to be administered at the rate of 2.3 mL/kg. How many mL of valium solution should be injected?

31.7 kg dog

73 mL soln

Starting quantity x **Conversion factor(s)** = **Equivalent quantity**

The Factor-Label Method

- A 31.7-kg dog needs valium to suppress hysteria from 4th of July fireworks. The prepared solution needs to be administered at the rate of 2.3 mL/kg. How many mL of valium solution should be injected?

$$31.7 \text{ kg dog} \times \frac{2.3 \text{ mL soln}}{1.0 \text{ kg dog}} \qquad 73 \text{ mL soln}$$

Starting quantity x **Conversion factor(s)** = **Equivalent quantity**

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$$31.7\ \cancel{\text{kg dog}} \quad \text{x} \quad \frac{2.3\ \text{mL soln}}{1.0\ \cancel{\text{kg dog}}} \qquad 73\ \text{mL soln}$$

Units cancel

Starting quantity **x** **Conversion factor(s)** **=** **Equivalent quantity**

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Do the math: $\boxed{\dfrac{31.7 \times 2.3}{1.0}}$

Starting quantity x **Conversion factor(s)** = **Equivalent quantity**

The Factor-Label Method

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Do the math: $\boxed{72.91}$

Starting quantity x **Conversion factor(s)** = **Equivalent quantity**

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Round to 2 s.f.: $\boxed{72.91}$

Starting quantity **x** **Conversion factor(s)** **=** **Equivalent quantity**

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Starting quantity x Conversion factor(s) = Equivalent quantity

Chained calculations...

- Sometimes it is necessary to string several conversion factors together to get from one set of units to another
- The same strategy holds -- arrange each term so that units cancel and work towards those associated with the final answer

Chained calculations...

- Let’s develop the relationship between hectares and acres
- A hectare is the metric unit used to describe the area of a forest stand or the habitat used by a species of wildlife
- A hectare is a square measuring 100 meters on a side

Chained calculations...

$(100\ \text{m})^{2}$

Chained calculations...

$(100\ \text{m})^2$

Look up conversion factors.

A useful start is:

1.00 m = 3.28 ft

(I'll always provide these in the problem if they're "unusual")

Chained calculations...

$$(100\ \text{m})^2 \times \frac{(3.28\ \text{ft})^2}{(1.00\ \text{m})^2}$$

Include it twice since meters appears twice, i.e., it's squared

Chained calculations...

$$(100\ \cancel{m})^2 \quad x \quad \frac{(3.28\ ft)^2}{(1.00\ \cancel{m})^2}$$

Cancel meters^2

Chained calculations...

$$(100\ \cancel{m})^2 \times \frac{(3.28\ ft)^2}{(1.00\ \cancel{m})^2}$$

Find next conversion factor

$1.0000\ acre = (208.71\ ft)^2$

Chained calculations...

$$(100\ \cancel{m})^2 \times \frac{(3.28\ ft)^2}{(1.00\ \cancel{m})^2}$$

$$\times \frac{1.0000\ acre}{(208.71ft)^2}$$

Add the new factor to the chain

Chained calculations...

$$(100\ \cancel{\text{m}})^2 \times \frac{(3.28\ \cancel{\text{ft}})^2}{(1.00\ \cancel{\text{m}})^2} \times \frac{1.0000\ \text{acre}}{(208.71\ \cancel{\text{ft}})^2}$$

Cancel ft^2

Chained calculations...

$$(100\ \cancel{m})^2 \times \frac{(3.28\ \cancel{ft})^2}{(1.00\ \cancel{m})^2}$$

$$\times \frac{1.0000\ \text{acre}}{(208.71\ \cancel{ft})^2}$$

Do the math

Chained calculations...

$$(100\ \cancel{m})^2 \times \frac{(3.28\ \cancel{ft})^2}{(1.00\ \cancel{m})^2}$$

$$\times \frac{1.0000\ \text{acre}}{(208.71\ \cancel{ft})^2}$$

Do the math

$$\frac{100 \times 100 \times 3.28 \times 3.28 \times 1.0000}{1.00 \times 1.00 \times 208.71 \times 208.71}$$

Chained calculations...

$$(100\ \cancel{m})^2 \times \frac{(3.28\ \cancel{ft})^2}{(1.00\ \cancel{m})^2}$$

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Ignore the 1's

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$$\times \frac{1.0000\ \text{acre}}{(208.71\ \cancel{ft})^2}$$

Do the math

$$\frac{100 \times 100 \times 3.28 \times 3.28}{208.71 \times 208.71} = 2.47$$

Chained calculations...

$$(100\ \cancel{m})^2 \times \frac{(3.28\ \cancel{ft})^2}{(1.00\ \cancel{m})^2}$$

$$\times \frac{1.0000\ \text{acre}}{(208.71\ \cancel{ft})^2}$$

Do the math $= \quad 2.47$ acre

Chained calculations...

$$(100\ \cancel{\text{m}})^2 \times \frac{(3.28\ \cancel{\text{ft}})^2}{(1.00\ \cancel{\text{m}})^2} \times \frac{1.0000\ \text{acre}}{(208.71\ \cancel{\text{ft}})^2} = 2.47\ \text{acre}$$

Chained calculations...

- Note we now have a new conversion factor available!
  - 1.00 ha = 2.47 acres

A Hectare calculation...

- A healthy stand of *Pinus ponderosa* has 250 trees per acre. What is the equivalent stand density in terms of trees per hectare?

The Factor-Label Method

- Uses conversion factors to go between unit systems

Starting quantity **x** **Conversion factor(s)** **=** **Equivalent quantity**

Chained calculations...

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- Let's use it to do a calculation Jane (G. Wiz's wife) says gets messed up all the time by her staff writers...

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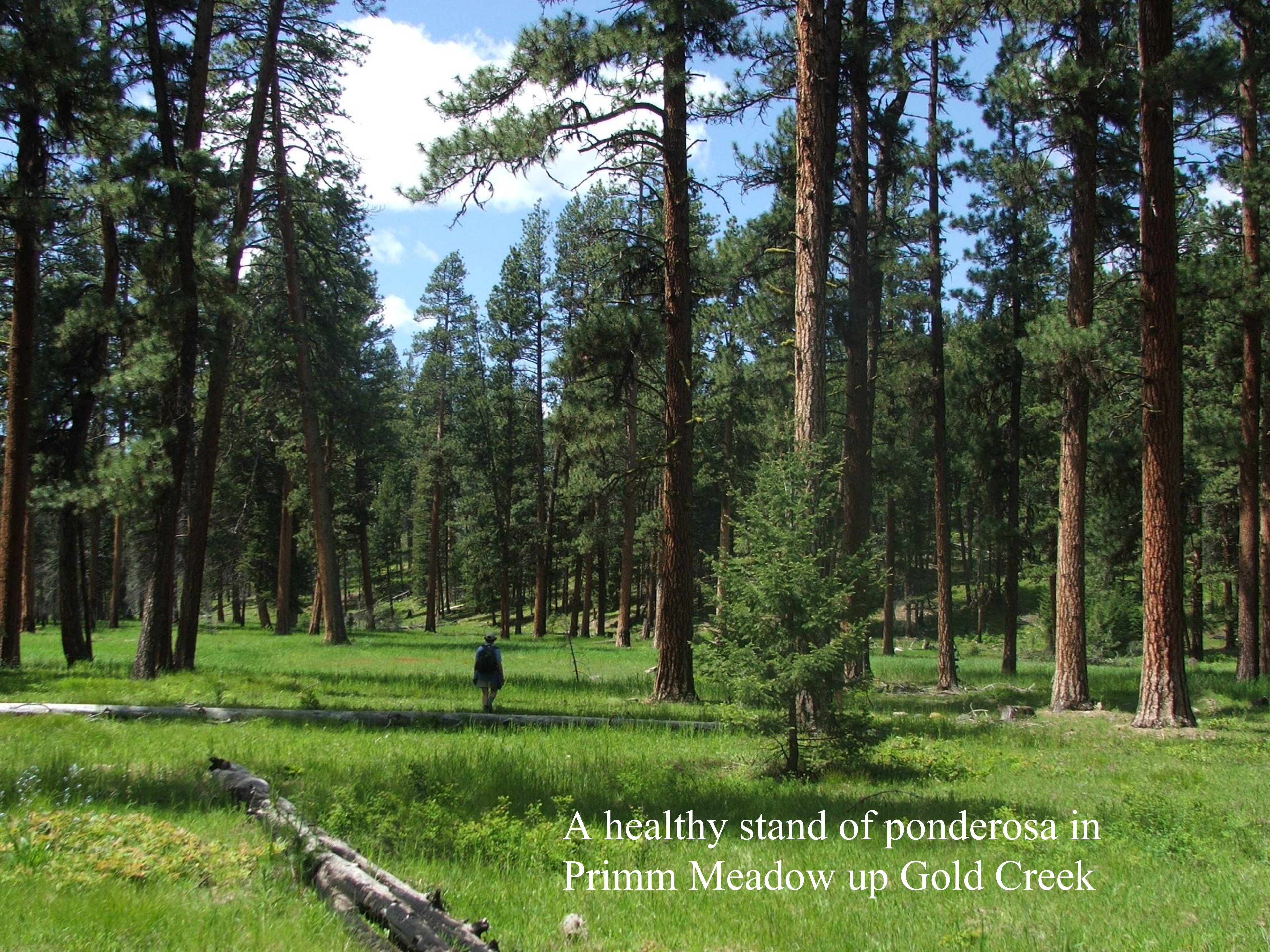

A healthy stand of ponderosa in
Primm Meadow up Gold Creek


Plum Creek
PRIMM'S
MEADOW
Permanently protected in a
conservation easement in 2005
Dedicated to David D. Leland for his
leadership and service to Plum Creek

A Hectare calculation...

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Note starting units

A Hectare calculation...

- A healthy stand of *Pinus ponderosa* has 250 trees per acre. What is the equivalent stand density in terms of trees per hectare?

$$\frac{250 \text{ trees}}{1 \text{ acre}}$$

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Determine units to get answer

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$$\frac{250\ \text{trees}}{1\ \text{acre}} \times \frac{2.47\ \text{acre}}{1.00\ \text{ha}} = \frac{\text{trees}}{\text{ha}}$$

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- Note we now have a new conversion factor available!

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Next, use our new conversion factor!

A Hectare calculation...

- A healthy stand of *Pinus ponderosa* has 250 trees per acre. What is the equivalent stand density in terms of trees per hectare?

$$\frac{250 \text{ trees}}{1 \text{ acre}} \times \frac{2.47 \text{ acre}}{1.00 \text{ ha}} = \frac{\text{trees}}{\text{ha}}$$

See, acres cancel out.

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$$\boxed{250 \times 2.47}$$

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617.5

A Hectare calculation...

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2 s.f.

$$\frac{250\ \text{trees}}{1\ \cancel{\text{acre}}} \times \frac{2.47\ \cancel{\text{acre}}}{1.00\ \text{ha}} = \frac{620\ \text{trees}}{\text{ha}}$$

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http://feis-crs.org/beta/

Chemistry: The Study of Change

Lessons Learned

- Distinguish between physical and chemical changes. Especially with heat
- Use scientific notation in calculations
- Understand significant figure limitations

Chemistry: The Study of Change
Lessons Learned

- Perform conversions from one unit to another including temperatures among Fahrenheit, Celsius and Kelvin
- Use metric units and prefixes for mass, length, volume, etc.
- Apply the factor-label method