

1. Screencasts

1.1 System of Units/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=rFS9wtB4KM0>

Systems of Units

Base Units

Quantity	SI Units	American Units	Symbols
Length	meter kilometer centimeter	foot inch	m, km, cm ft, in
Mass	kilogram gram	pound	kg, g lb
Moles	g-mole kilog-mole	pound-moles	mols, kmols lb-moles
Time	second minute, hour		s, min, h
Temperature			

And finally, we look at temperature.

Figure 1 - System of Units by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.2 Unit Conversion (practice)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=mgR6egNSoJc>

How many moles of water are in 1 cup?

$$\frac{1 \text{ cup H}_2\text{O}}{1 \text{ m}^3 \text{ H}_2\text{O}} \times \frac{1 \text{ m}^3}{1000 \text{ L}} \times \frac{1000 \text{ L}}{1 \text{ m}^3} \times \frac{1 \text{ mole}}{18 \text{ g H}_2\text{O}} \times \frac{240 \text{ g}}{1 \text{ cup}} = \frac{240}{18}$$

$x = 13.3 \text{ moles H}_2\text{O}$

Can you out run an alligator able to dash at 20 mph if you can cover the 40 yd dash in 5 seconds?

$$\frac{40 \text{ yd}}{5 \text{ s}} \times \frac{3600 \text{ s}}{1 \text{ hr}} \times \frac{3 \text{ ft}}{1 \text{ yd}} \times \frac{1 \text{ mi}}{5280 \text{ ft}} \times \frac{\text{miles}}{\text{hr}} = 164 \text{ mph}$$

Cheaper to drive in US with 20 miles/gallon or in Germany with 6 Liters / 100 km

and that's how they report it over there. So there's a couple different conversions you have to make.

Figure 2 - Unit Conversion by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.3 Unit Conversion (Example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/laMyHmqsTUo>

Unit Conversion Example 1
Units conversion

A sample of oil has a density of 0.85 g/mL. What is the mass of 3.00 barrels of oil in kilograms if a barrel of oil is 42.0 gallons? You are given that one gallon is equal to 3.8754 L.

$\rho = 0.85 \text{ g/mL}$ mass in kg?
3.00 barrels 1 barrel = 42.0 gal 1 gal = 3.8754 L

$\frac{3.00 \text{ barrels}}{1 \text{ barrel}}$

to carry the units through. Three barrels and 1 barrel is 42.0 gal. I am writing it

Figure 3 - Unit conversion Example by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.4 Molecular Mass/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=V5zzzzWuwzE>

Molecular Mass (Example)

Calculate molecular mass

What is the molecular mass of $\text{C}_8\text{H}_6\text{Cl}_2\text{O}_3$?

8	C	amu	12.011
6	H		1.008
2	Cl		35.453
3	O		15.999

First I'll multiply this by eight, this by six, this by two

Figure 4 - Molecular Mass (Example) by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.5 Number of Subatomic particles/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=oHAuPT3Mk3Y>

Number of Protons Neutrons Electrons (Example)
Count protons, neutrons, electrons
How many protons, neutrons and electrons are in the following anionic compound: $C_2H_5O^-$?

		protons	neutrons	electrons
2	C	2x6		
5	H	5x1		
1	O		8	

atomic number = # of protons
of neutrons = atomic weight(rounded to whole number) - # protons
Neutral atoms have equal #'s of protons and electrons.
two carbons, five times, and then one times this

Figure 5 - Subatomic particles by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.6 Isotopic Abundance Example/LearnChemE (CC BY-SA 4.0 DEED)

https://www.youtube.com/watch?v=agUT0ekqs_A

Isotope Composition (Example)
Isotopic composition
A sample of naturally occurring silicon consists of ^{28}Si (27.9769 amu), ^{29}Si (28.9765 amu) and ^{30}Si (29.9738 amu). If the atomic mass of silicon is 28.0855 amu, and the natural abundance of ^{29}Si is 4.67% what is the natural abundance of ^{28}Si ?

^{28}Si :	X		
^{29}Si :	4.67%	Avg	28.0
^{30}Si :	$100 - X - 4.67$		

and we know the average, and that's 28.0855

Figure 6 - Isotope composition by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.7 Empirical formula from mass percentage/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=SGyj0sySvhM>

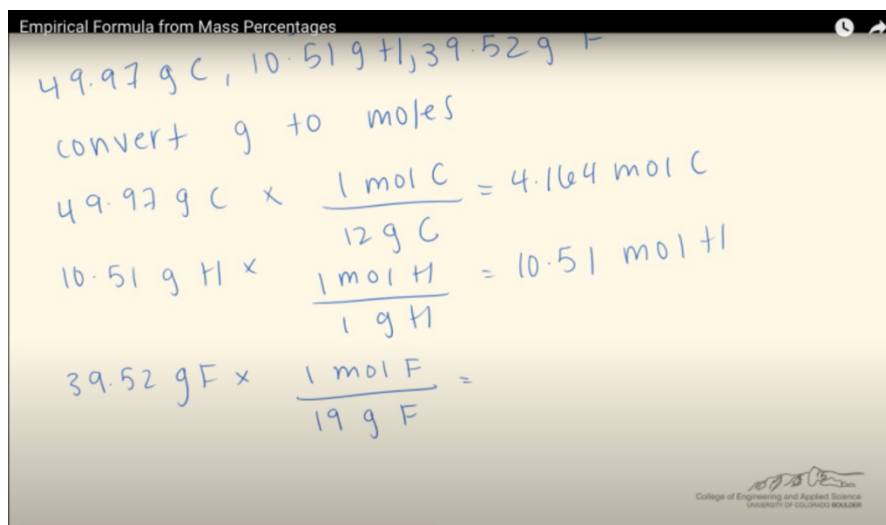


Figure 7 - Empirical formula by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.8 Empirical formula from combustion analysis example/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=aonEmARxw8M>

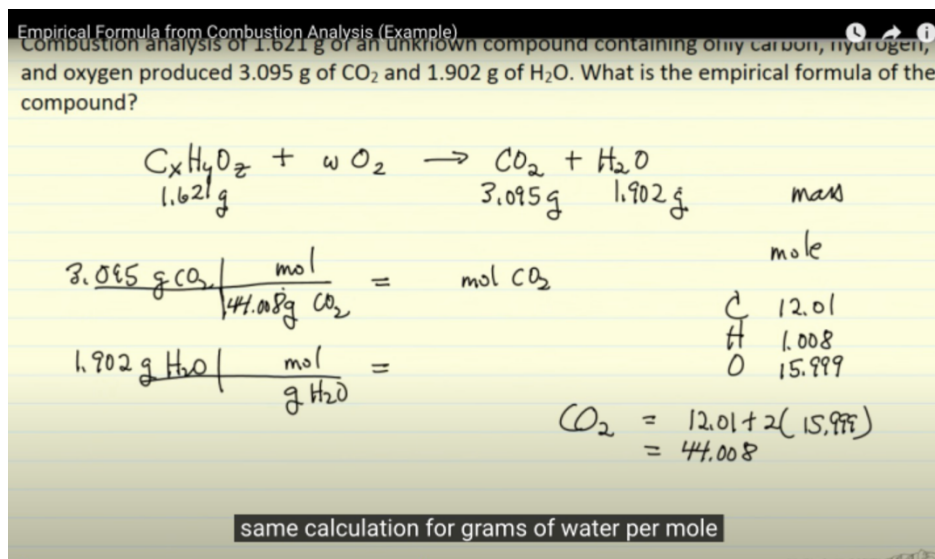


Figure 8 - Empirical formula from combustion analysis by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.9 Empirical formula from combustion analysis 2/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=tbMfvqu191Y>

Empirical Formula from Combustion Analysis 2 (Example)

Combustion analysis

1.00 g of a compound containing carbon, hydrogen and oxygen produces 1.161 g of H₂O and 2.818 g of CO₂ when it completely reacts with oxygen. What is the empirical formula for this compound?

In this example, we're gonna look at combustion

Figure 9 - Empirical formula from combustion analysis by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.10 Mass composition from molar composition/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=S4Jzn4lyc6k>

Mass Composition from Molar Composition (Example)

Mass composition from molar composition

DDT is an insecticide that is composed of C, H, and Cl and has the molecular formula C₁₄H₉Cl₅. What is the percentage composition of DDT by mass?

C ₁₄ H ₉ Cl ₅ mass composition		atomic mass (g/mol)
14 mol C	$\times \frac{12.01 \text{ g}}{\text{mol}} = \text{g C}$	C 12.01
9 mol H	$\times 1.008$	H 1.008
5 mol Cl		Cl 35.45

9 moles of hydrogen, and there's 1.008 g/mol

Figure 10 - Mass Composition from molar composition by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.11 Balance an equation/LearnChemE (CC BY-SA 4.0 DEED)

https://www.youtube.com/watch?v=a0Gvh_JvJgY

Balance an Equation (Example)

Balance equation

Balance the following chemical equation:

$$\text{NH}_4\text{NO}_3 \rightarrow \text{N}_2 + \text{O}_2 + \text{H}_2\text{O}$$

left n

So if we compare the left and the right

Figure 11 - Balance on Equation by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.12 Calculate the amount of reactant needed/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=zNP0-2w6qrs>

Calculate Amount of Reactant Needed (Example)

Calculate amount of reactant needed

Reacting Fe_2O_3 with CO produces pure Fe and CO_2 . How many grams of CO are needed to react with with 3.02 g of Fe_2O_3 ?

$$\begin{array}{l} \text{Fe}_2\text{O}_3 + 3\text{CO} \rightarrow 2\text{Fe} + 3\text{CO}_2 \\ 3.02 \text{ g} \quad \quad \quad \times \end{array}$$

And the question, what I don't know is

Figure 12 - Calculate the amount of reactant needed LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.13 Stoichiometry/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=e8cUyGBt8e8>

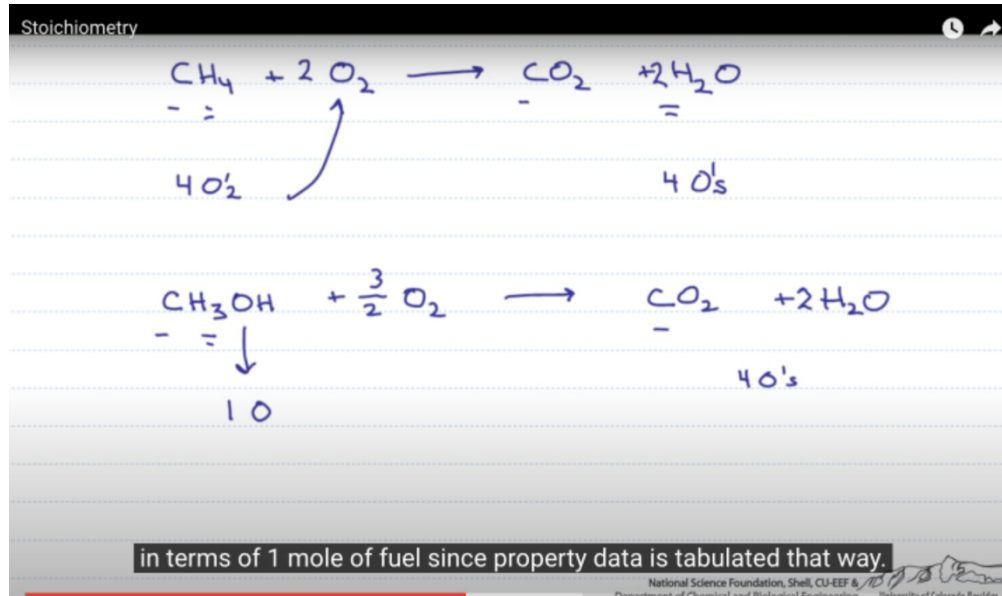


Figure 13 - Stoichiometry by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.14 Reaction stoichiometry (interactive)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=s7AYHkMbFNs>

Reaction Stoichiometry (Interactive)

Consider the reaction $A + B \rightarrow C$. The molecular weight is 50 g/mol for A and 100 g/mol for B. If 10 g of A are consumed in a reaction, how many g of C form?

A. 10 g B. 15 g C. 20 g D. 30 g

E. Need MW of C

grams of C do we form? Do we form 10 grams of C? 15 grams of C? 20 grams of C? 30 grams

Figure 14 - Stoichiometry interactive by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.15 Calculate concentration (example)/LearnChemE (CC BY-SA 4.0 DEED)

https://www.youtube.com/watch?v=nvjoBkH8_qQ

Calculate concentration

What is the volume of the solution that would result by diluting 70.00 mL of 0.0913 M NaOH to a concentration of 0.0150 M?

0.0913 M → 0.0150 M
20.00 mL add $V_2 = ?$
 water

mass NaOH ← mass NaOH
mole mole

0

Figure 15 - Stoichiometry interactive by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.16 Calculate concentration (example)/LearnChemE (CC BY-SA 4.0 DEED)

https://www.youtube.com/watch?v=nvjoBkH8_qQ

Calculate concentration

What is the volume of the solution that would result by diluting 70.00 mL of 0.0913 M NaOH to a concentration of 0.0150 M?

0.0913 M → 0.0150 M
20.00 mL add $V_2 = ?$
 water

mass NaOH ← mass NaOH
mole mole

0

Figure 16 - Calculate concentration by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.17 - Create diluted solution (example)/LearnChemE (CC BY-SA 4.0 DEED)

https://www.youtube.com/watch?v=MybrJJdx_Gw

Create Diluted Solution (Example)
Create diluted solution

You have 40.0 mL of a 2.0 M HCl solution. How many mL of H₂O must be added to make a 0.5 M HCl solution?

$$\begin{array}{ccc} 2.0 \text{ M HCl} & \longrightarrow & 0.5 \text{ M HCl} \\ 40.0 \text{ mL} & & \end{array}$$
$$\frac{2 \text{ mol}}{\text{L}} \Big| 40.0 \text{ mL} \Big| \frac{\text{L}}{10^3 \text{ mL}} =$$

of HCl. Notice the units cancel to give me moles

Figure 17 - Create diluted solution by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.18 - Precipitation reaction (Spectator Ions)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=R6wwlsYCR6c>

Precipitation Reaction (Spectator Ions) (Example)
Precipitation reaction

Sodium sulfate (Na₂SO₄) and calcium hydroxide (Ca(OH)₂) are both individually soluble in water. However, after both are dissolved in the same water solution, they form a solid CaSO₄ precipitate. What are the spectator ions for this precipitation reaction?

$$\text{Na}_2\text{SO}_4$$

And that is I'm adding sodium sulfate and calcium

Figure 18 - Precipitation reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.19 Titration (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=OZv2qi1NoPc>

Titration (Example)

Titration

What volume of 0.2 M H_3PO_4 is required to titrate 120 mL of 0.05 M NaOH to equivalence?

$$\begin{array}{ccc} \text{H}_3\text{PO}_4 & + & 3 \text{NaOH} & \rightarrow & \text{Na}_3\text{PO}_4 & + & 3 \text{H}_2\text{O} \\ 0.2 \text{ M} & & 0.05 \text{ M} & & & & \\ & & 120 \text{ mL} & & & & \end{array}$$
$$\frac{120 \text{ mL}}{1} \left| \frac{0.05 \text{ mol NaOH}}{\text{L}} \right|$$

moles of sodium hydroxide per liter. Let's keep the units consistent. This then is the

Figure 19 - Titration by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.20 Titrate Base with acid (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=h-RlXX9UnfM>

Titrate Base With Acid (Example)

Titration

What volume of 0.15 M H_2SO_4 is required to titrate 30 mL of 0.052 M NaOH to equivalence?

$$\begin{array}{ccc} \text{H}_2\text{SO}_4 & + & 2 \text{NaOH} & \rightarrow & \text{Na}_2\text{SO}_4 & + & 2 \text{H}_2\text{O} \\ 0.15 \text{ M} & & 0.052 \text{ M} & & & & \\ x? & & 30 \text{ mL} & & & & \end{array}$$

in this type of problem is to use the units to make it easier to solve the problem. If

Figure 20 - Titrate base with acid by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.21 Oxidizing and reducing agents (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=142KSemCU0k>

Oxidizing and Reducing Agents (Example)

Oxidizing and reducing agents

In the following reaction as written what species is the reducing agent and what species is the oxidizing agent?

$$\text{Ag}(s) + \text{NO}_3^-(aq) \rightarrow \text{Ag}^+(aq) + \text{NO}_2(g)$$

oxidation : the gain of oxygen atoms
the loss of electrons

reduction : the loss of oxygen atoms
the gain of electrons

oxidizing as

is reduced, and then likewise, for reduction

Figure 21 - Oxidizing and reducing agents by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.22 Oxidation number (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=OT9SxW8IsBg>

Oxidation Number (Example)

Determine oxidation number

What is the oxidation number of Mn in MnO_3^{2-} ?

-2

O^{2-}

$3(-2) + y$

that's the oxidation number on manganese

Figure 22 – Oxidation number by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.23 Oxidation number 2 (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://www.youtube.com/watch?v=-K-2f0g2wro>

Oxidation Number 2 (Example)

Oxidation numbers

What are the oxidation numbers of V, O and Cl in the compound VOCl_3 ?

$\overset{-2}{\text{O}}$

V O Cl_3

And in this compound, we would assign an oxidation

Figure 23 - Oxidation number 2 by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.24 Balance redox reaction (acidic solution)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/EE8fjXiX-Lc>

Balance Redox Reaction: Acidic Solution (Example)

What is the balanced net ionic equation for the following reaction in acidic solution?

$\text{Mg(s)} + \text{VO}_4^{3-}(\text{aq}) \rightarrow \text{Mg}^{2+}(\text{aq}) + \text{V}^{2+}(\text{aq})$

① half reactions

$[\text{Mg} \rightarrow \text{Mg}^{2+} + 2\text{e}^-]$

② Balance O

③ Balance H

$3\text{e}^- + 8\text{H}^+ + \text{VO}_4^{3-} \rightarrow \text{V}^{2+} + 4\text{H}_2\text{O}$

④ Balance charge e^-

Such as to cancel out the electrons

Figure 24 - Balance redox reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.25 Balance redox reaction (acidic solution 2)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/94T84t8Xjzw>

LearnChemE Balance Redox Reaction: Acidic Solution 2 (Example) Copy link

Redox reaction

Write a net ionic equation for the following redox reaction in acidic solution. Note that the half-reaction method can be applied to this problem.

$$\text{IO}_3^- (\text{aq}) + \text{I}^- (\text{aq}) \rightarrow \text{I}_2 (\text{aq})$$

$$16e^- + 18\text{H}^+ + 3\text{IO}_3^- \rightarrow \text{I}_2 + 9\text{H}_2\text{O}$$

$$3\text{I}^- \rightarrow \text{I}_2$$

-3 -1

(1) half reactions
(2) balance O, balance H
(3) charge
(4) 0

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Figure 25 - Balance redox reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.26 Balance redox reaction (basic solution)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/bCQf0rVJe8c>

LearnChemE Balance Redox Reaction: Basic Solution (Example) Copy link

Balance redox reaction

When the following redox reaction is balanced in basic aqueous solution, with the smallest possible integer coefficients, what is the stoichiometric coefficient of H_2O ?

$$\text{SeO}_2 + \text{Cl}_2 \rightarrow \text{SeO}_4^{2-} + \text{Cl}^-$$

$$3\text{H}_2\text{O} + \text{SeO}_2 \rightarrow \text{SeO}_4^{2-} + 6\text{H}^+ + 6e^-$$

$$2e^- + \text{Cl}_2 \rightarrow 2\text{Cl}^-$$

(1) half reactions
(2) balance O, balance H
(3) charge

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Figure 26 - Balance redox reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.27 Ideal gas properties (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/cBTaIZFIEG4>

The screenshot shows a video player interface for a video titled "Ideal Gas Properties (Example)". The video content includes a problem statement: "A 1.00 L flask contains nitrogen gas at 25°C and 1.00 bar pressure. What is the final pressure in the flask if an additional 2.00 g of N₂ gas is added to the flask and the flask cooled to -55°C?". Below the text, handwritten calculations are shown on a yellow background. The calculations include: "1.00 L, 25°C, 1.00 bar" for the initial state; "+ 2.00 g N₂ → cool to -55°C" for the changes; a calculation for the moles of added gas: $\frac{2.00 \text{ g}}{28.014 \text{ g/mol}} = 0.07142 \text{ mol added}$; the ideal gas law $PV = nRT$; and the calculation for the initial moles: $n = \frac{PV}{RT} = \frac{(1.00 \text{ bar})(1.00 \text{ L})}{(0.0831 \frac{\text{bar}\cdot\text{L}}{\text{mol}\cdot\text{K}})(25+273.2 \text{ K})} = 0.04033 \text{ mol}$. A red play button is overlaid on the calculations. At the bottom of the video player, it says "Watch on YouTube".

Figure 27 - Ideal gas properties by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.28 Ideal gas law example/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/lqUS4_0m9Zc

The screenshot shows a video player interface for a video titled "Ideal Gas Law Example (Example)". The video content includes a problem statement: "Nitrogen gas is in a 45.0 L container at 125 bar. What volume would the nitrogen occupy at a pressure of 5.0 bar if the temperature did not change?". Below the text, it says "Note: Not using the same container." A blue box with a red play button contains the text "SUGGESTION: Pause to solve on your own." At the bottom of the video player, it says "Watch on YouTube".

Figure 28 - Ideal gas law example by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.29 Molar mass of a gas/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/mF8RdjDiuu8>

The screenshot shows a video player interface for a video titled "Molar Mass of a Gas (Example)". The video content includes the following text and equations:

Calculate molar mass of gas
If the pressure of gaseous chloroform in a flask is 195 mm Hg at 25°C and its density is 1.25 g/L, what is the molar mass of chloroform?

$$PV = nRT$$
$$\frac{n}{V} = \frac{P}{RT}$$

mass/volume = 1.25

Watch on YouTube

Figure 29 - Molar mass of a gas by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.30 Gas density/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/EhPx3La_Zg

The screenshot shows a video player interface for a video titled "Gas Density (Example)". The video content includes the following text and equations:

Gas densities
Which gas is the most dense (g/cm³) at STP?
F₂ Cl₂ Kr O₂ Xe

$$PV = nRT$$
$$\frac{n}{V} = \frac{P}{RT}$$

constant

mass/volume higher n wgt

F ₂	19.0
Cl ₂	35.4
Kr	83.8
O ₂	16.0
Xe	131.1

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Figure 30 - Gas density by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.31 Partial pressure/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/iCTnUFlakNo>

Partial Pressures (Example)

Partial pressures

A container has 22 g CO₂ and 156 g C₆H₆. The total pressure at 100°C is 10.0 bar. What are the partial pressures?

$$P_{\text{CO}_2} = y_{\text{CO}_2} P$$

$$P_{\text{C}_6\text{H}_6} = y_{\text{C}_6\text{H}_6} P$$

$$\frac{22 \text{ g CO}_2}{\frac{\text{mol CO}_2}{\text{g CO}_2}} =$$

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Figure 31 - Partial pressure reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.32 Amount of gas product formed/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/LXYdJN1V_p0

Amount of Gas Product Formed (Example)

Calculate amount of gas phase product

Limestone reacts with hydrochloric acid according to the equation:

$$\text{CaCO}_3 + 2 \text{HCl} \rightarrow \text{H}_2\text{O} + \text{CO}_2 + \text{CaCl}_2$$

How many liters of CO₂ form at STP by reacting 2.35 g of CaCO₃ with 2.35 g of HCl?

$$\frac{2.35 \text{ g CaCO}_3}{\frac{1 \text{ mol CaCO}_3}{\text{g CaCO}_3}} = \text{mol CaCO}_3$$

$$\frac{2.35 \text{ g HCl}}{\frac{1 \text{ mol HCl}}{\text{g HCl}}} = \text{mol HCl}$$

Ca	40.08
C	12.01
O	16.00
H	1.08
Cl	35.46

Atomic weight for H is actually 1.008. Very slight change - doesn't affect results.

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Figure 32 - Amount of gas formed by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.33 Changes in enthalpy and internal energy/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/W0zUnmr9r4U>

Learn ChemE Changes in Enthalpy and Internal Energy (Example) Copy link

Calculate changes in enthalpy and internal energy

A process was carried out at a pressure of 12 bar. The heat added was 125 kJ and the volume increased by 12.4 L. What are the values of ΔE and ΔH ?

$$\Delta H = \Delta E + \Delta PV$$
$$= \Delta E + P\Delta V$$
$$\Delta E = Q + W$$
$$W = -P\Delta V$$

$-12 \text{ bar} (12.4 \text{ L}) \left| \frac{0.1 \text{ kJ}}{1 \text{ bar L}} \right.$

Watch on YouTube

Figure 33 - Changes in enthalpy and internal energy by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.34 Enthalpy and internal energy changes/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/p_mmzNtqidl

Learn ChemE Enthalpy and Internal Energy Changes (Example) Copy link

Enthalpy and internal energy changes

For which of the reactions shown below is ΔE^* larger than ΔH^* ?

A. $2 \text{ SO}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{ SO}_3(\text{g})$

B. $\text{C}_2\text{H}_2(\text{g}) + 5 \text{ O}_2(\text{g}) \rightarrow 3 \text{ CO}_2(\text{g}) + 4 \text{ H}_2\text{O}(\text{l})$

C. $\text{H}_2(\text{g}) + \text{Cl}_2(\text{g}) \rightarrow 2 \text{ HCl}(\text{g})$

D. $\text{N}_2\text{O}_4(\text{g}) \rightarrow 2 \text{ NO}_2(\text{g})$

E - internal energy
H - enthalpy

SUGGESTION:
Pause and try to solve
on your own.

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Figure 34 - Enthalpy and internal energy changes by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.35 Heat absorbed during a reaction/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/D3Vh4eVN87M>

Learn ChemE Heat Absorbed During a Reaction (Example) Copy link

Heat adsorbed during reaction

How much heat is absorbed when 45.0 g of C(s) reacts in the presence of excess SO₂(g) to produce CS₂(l) and CO(g) according to the following chemical equation?

$$5 \text{ C(s)} + 2 \text{ SO}_2\text{(g)} \rightarrow \text{CS}_2\text{(l)} + 4 \text{ CO(g)} \quad \Delta H^\circ = 239.9 \text{ kJ}$$

45g excess ← 5 mol carbon

$$\frac{45 \text{ g C}}{12.01 \text{ g/c}}$$

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Figure 35 - Heat absorbed during a reaction by LearnChemE is licensed under CC BY-SA 4.0-LearnChemE

1.36 Heat of reaction/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/gYZroO3mAlw>

Learn ChemE Heat of Reaction (Example) Copy link

When 1.50 g of Li(s) is added to 100.0 g of water, the temperature of the resulting solution rises from 22.0°C to 33.1°C. If the specific heat of the solution is 4.18 J/(g · °C), calculate ΔH for the reaction, as written.

$$2 \text{ Li(s)} + 2 \text{ H}_2\text{O(l)} \rightarrow 2 \text{ LiOH(aq)} + \text{ H}_2\text{(g)}$$

$$2 \text{ Li} + 2 \text{ H}_2\text{O} \rightarrow 2 \text{ LiOH} + \text{ H}_2$$

1.50 g
mol

$$\Delta H = m C_p \Delta T = (100.0 \text{ g}) \left(\frac{4.18 \text{ J}}{\text{g} \cdot ^\circ\text{C}} \right)$$

Watch on YouTube

Figure 36 - Heat of Reaction reaction by LearnChemE is licensed under CC BY-SA 4.0-LearnChemE

1.37 Hess's law/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/OHptjNxKNXs>

Hess's Law

Link copied to clipboard

All reactants must appear on the left / products on right
cancel out on both the left and right
- change the sign
reaction, multiply/divide the enthalpy

SUGGESTION:
Pause and try to solve
on your own.

$$\text{CH}_4(\text{g}) + 2\text{O}_2(\text{l}) \rightarrow \text{CO}_2(\text{g}) + 2\text{H}_2\text{O}(\text{l})$$

CH₄(g) + O₂(g) → CH₂O(g) + H₂O(l) -284 kJ
 CO₂(g) + H₂O(l) → CH₂O(g) + O₂(g) 512 kJ
 H₂O(l) → H₂O(g) 44 kJ

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Figure 37 - Hess's law by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.38 Heat of reaction (Hess's law)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/e5J8oNMFRTe>

Heat of Reaction: Hess's Law (Example)

Copy link

Heat of reaction

Given the two reactions:

$$2 \text{CO}(\text{g}) + \text{S}_2(\text{g}) \rightarrow 2 \text{COS}(\text{g}) \quad \Delta H^\circ = -192 \text{ kJ}$$

$$2 \text{COS}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2 \text{CO}(\text{g}) + 2 \text{SO}_2(\text{g}) \quad \Delta H^\circ = -265 \text{ kJ}$$

What is the heat of reaction for S₂ oxidation?

$$\text{S}_2(\text{g}) + 2 \text{O}_2(\text{g}) \rightarrow 2 \text{SO}_2(\text{g})$$

Multiplied by 2 so that the stoichiometric coefficients would match those of the final equation

Watch on YouTube

Figure 38 - Heat of reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.39 Heat of reaction (Hess's law 2)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/gohO4DlpqQE>

Heat of reaction

Coal gasification can be represented by the equation:
 $2 \text{C}(s) + 2 \text{H}_2\text{O}(g) \rightarrow \text{CH}_4(g) + \text{CO}_2(g) \quad \Delta H = ?$

Use the following information to find ΔH for the above reaction .

$\text{CO}(g) + \text{H}_2(g) \rightarrow \text{C}(s) + \text{H}_2\text{O}(g) \quad \Delta H = -131 \text{ kJ}$
 $\text{CO}(g) + \text{H}_2\text{O}(g) \rightarrow \text{CO}_2(g) + \text{H}_2(g) \quad \Delta H = -41 \text{ kJ}$
 $\text{CO}(g) + 3 \text{H}_2(g) \rightarrow \text{CH}_4(g) + \text{H}_2\text{O}(g) \quad \Delta H = -205 \text{ kJ}$

SUGGESTION:
Pause and try to solve on your own.

Watch on YouTube

Figure 39 - Heat of reaction by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.40 Lewis structure (octet rule)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/gQ7Uwd4NZXk>

Lewis structures of Lewis Structures that do not obey the Octet Rule (Examples)

KBr CO₂ ClF₃ ICl (Iodine bonded to chlorine) HCN

$\text{K} : \text{Br} :$ ✓
 $\text{O} :: \text{C} :: \text{O}$ ✓
 $:\text{I} : \text{Cl} :$ ✓
 $\text{Cl} : \text{F} : \text{F} :$ Not octet

obeys octet rule

Watch on YouTube

Figure 40 - Lewis structure by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.41 Lattice Energy/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/ConTsQHnN6Q>

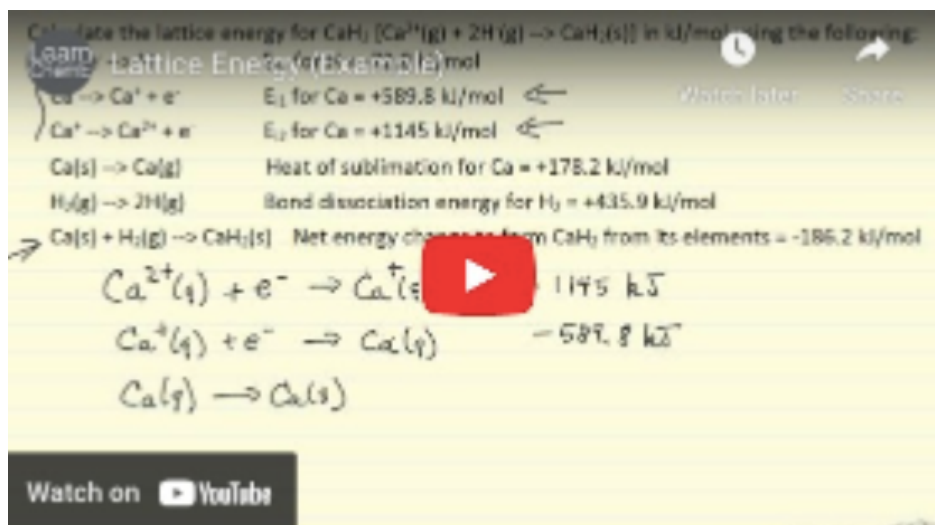


Figure 41 - Lattice energy by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.42 Lewis dot structure example/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/cMubkwFUEDA>

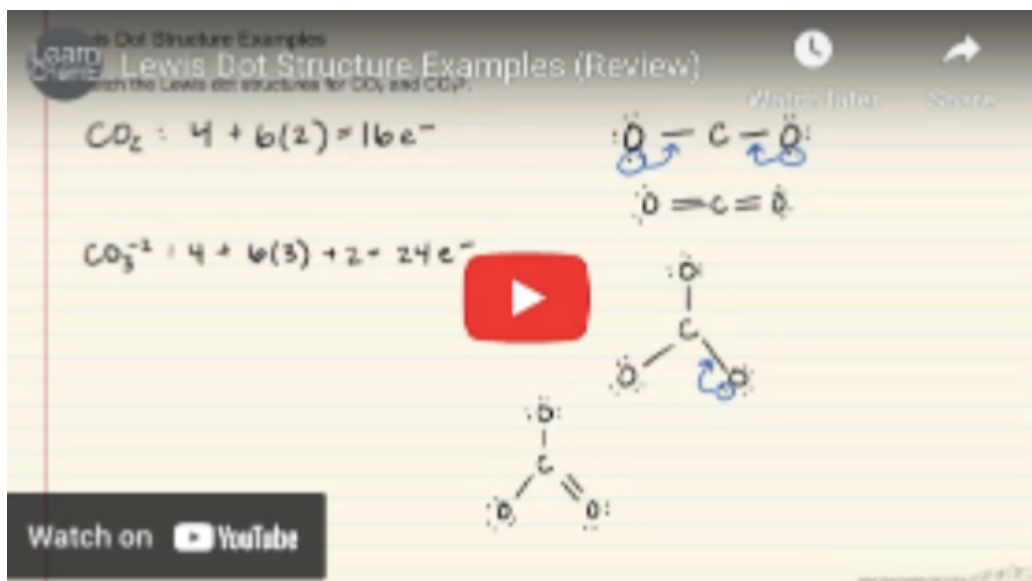


Figure 42 - Lewis dot structure by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.43 Lewis dot structure (molecular geometry)/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/V1iM_GwTlys

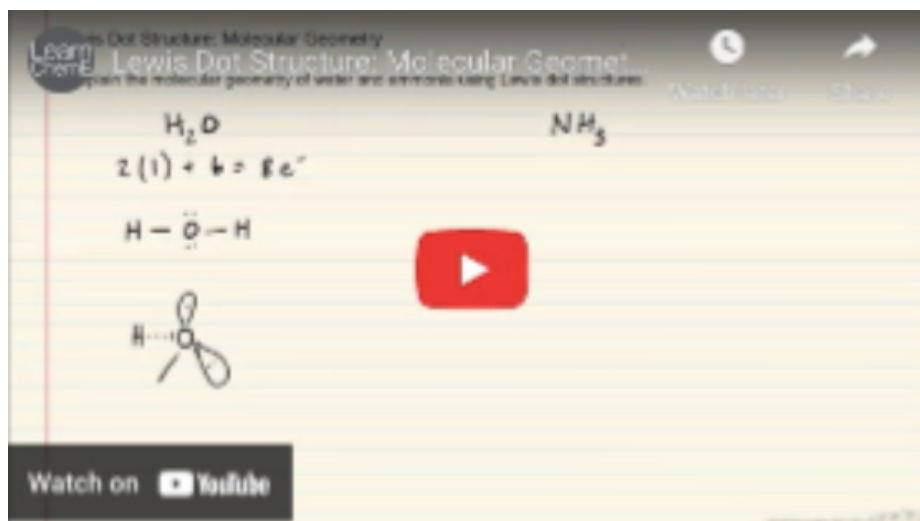


Figure 43 - Lewis dot structure by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.44 Lewis dot structure (triple bond)/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/6WkIC9e_M10



Figure 44 - Lewis dot structure by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.45 Formal Charge/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/_wYtocFdgGc

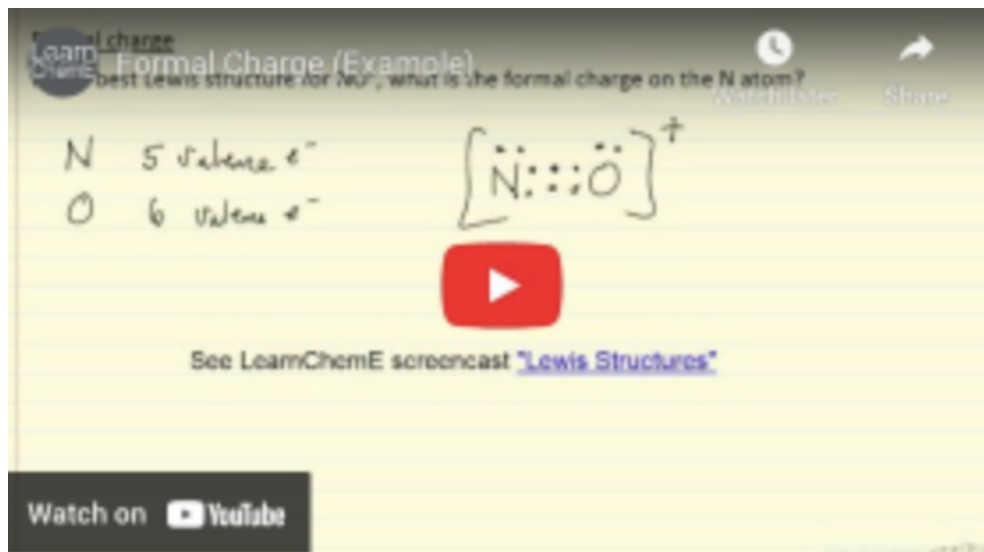


Figure 45 - Formal charge by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.46 Determining favored resonance structure/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/ILhTrWvGrZ8>



Figure 46 - Determining favored resonance structure by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.47 Molecular shape (VSEPR)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/vZ2Im4bxa4M>



Figure 47 - VSEPR by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.48 Molecular geometry/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/Cc88wFkW_aA



Figure 48 - Molecular geometry by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.49 Which molecule is non-polar?/LearnChemE (CC BY-SA 4.0 DEED)

https://youtu.be/_-nNBt19yTA

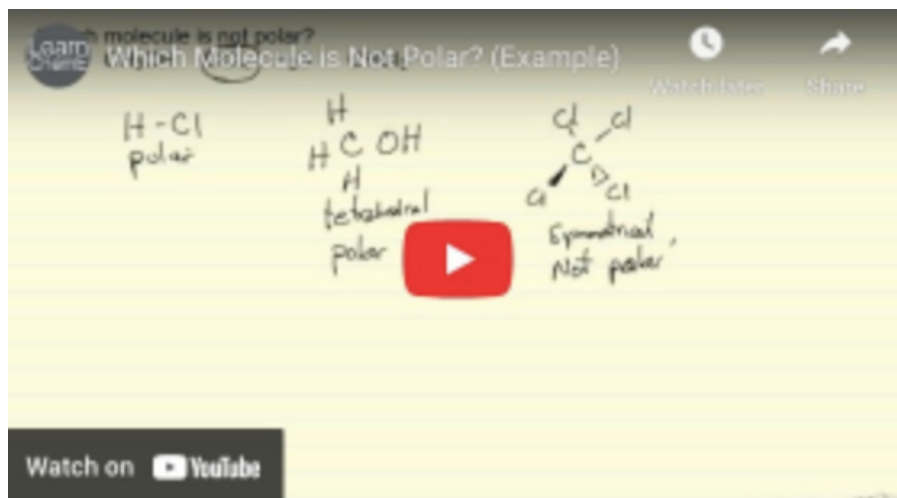


Figure 49 - Which molecule is non-polar? by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.50 Ranking vapor pressure/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/Fd6eqNyPSgl>



Figure 50 - Ranking vapor pressure by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.51 Heat of vaporization from vapor pressure/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/OGAxPWUB8H8>

Heat of Vaporization from Vapor Pressure (Example)

Heat of vaporization from vapor pressures

The vapor pressure of liquid chloroform, CHCl_3 , is 53.1 kPa at 24.1 °C and 13.3 kPa at -6.30°C. What is the heat of vaporization of chloroform?

$$\ln \frac{P_2}{P_1} = -\frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{T_2} - \frac{1}{T_1} \right)$$

absolute temperature

$$\ln \left(\frac{53.1}{13.3} \right) = -\frac{\Delta H_{\text{vap}}}{R} \left(\frac{1}{297.3} - \frac{1}{266.9} \right)$$

24.1 + 273.2 = 297.3
-6.3 + 273.2 = 266.9

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Figure 51 - Heat of Vaporization by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.52 Boiling point from PVT diagram/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/jZESbugbnWw>

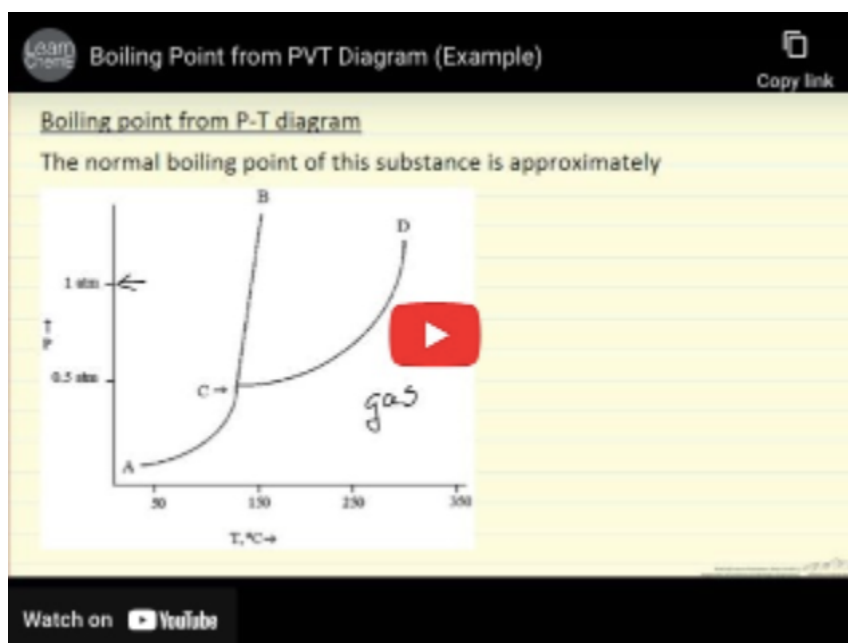


Figure 52 - Boiling point from PVT by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.53 Density of Iron (example)/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/s8MHZQpZOjc>

Density of Iron (Example)

Metal density from structure

Iron crystallizes in a body-centered cubic structure having an edge length of 287 pm. What is the density of iron in g/cm^3 ?

BCC

density = $\frac{\text{mass}}{\text{volume}}$

$1 + 8\left(\frac{1}{8}\right) = 2 \text{ atoms Fe}$

287 pm

55.85 $\frac{\text{g}}{\text{mol}}$

0¹² m

Watch on YouTube

Figure 53 - Density of iron by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

1.54 Density of an element/LearnChemE (CC BY-SA 4.0 DEED)

<https://youtu.be/Cwdef3TIOtE>

Density of an Element (Example)

Density of an element

Rhodium has a face-centered cubic structure and a density of 12.41 g/cm^3 . What is its atomic radius?

$a^3 = \text{volume}$

$\left(\frac{1}{2}\right)(6) = 3 \text{ atoms}$

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Figure 54 - Density of an element by LearnChemE is licensed under CC BY-SA 4.0- LearnChemE

2. Textbook Mapping

2.1 Chapter 1: Matter, measurements, and problem solving (CC BY-NC-SA 4.0)

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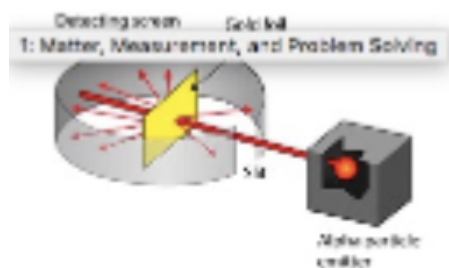


1: Matter, Measurement, and Problem Solving

Figure 55 - Text: Chapter 1: Matter, measurements, and problem solving, by Libretext, CC BY-NC-SA 4.0- Author:Tro

2.2 Chapter 2: Atoms and Elements (CC BY-NC-SA 4.0)

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2: Atoms and Elements

Figure 56 - Text: Chapter 2: Atoms and Elements, by Libretext, CC BY-NC-SA 4.0 Author:Tro

2.3 Chapter 3: Molecules, Compounds and Chemical Equations (CC BY-NC-SA 4.0)

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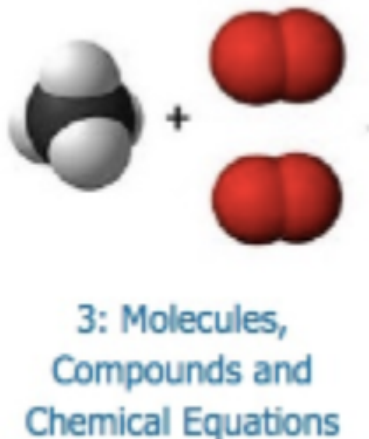


Figure 57 - Text: Chapter 3: Molecules, Compounds and Chemical Equations , by Libretext, CC BY-NC-SA 4.0 Author:Tro

2.4 Chapter 4: Chemical Reactions and aqueous solution (CC BY-NC-SA 4.0)

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4: Chemical Reactions and Aqueous Reactions

Figure 58 - Text: Chapter 4: Chemical Reactions and aqueous solution , by Libretext, CC BY-NC-SA 4.0 Author:Tro

2.5 Text: Chapter 5: Gases (CC BY-NC-SA 4.0)

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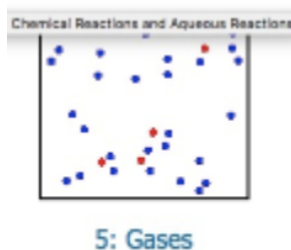


Figure 59 - Text: Text: Chapter 5: Gases , by Libretext, CC BY-NC-SA 4.0 Author:Tro

2.6 Chapter 6: Thermochemistry (CC BY-NC-SA 4.0)

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2.7 Chapter 7: The Quantum Mechanic Model of the Atom (CC BY-NC-SA 4.0)

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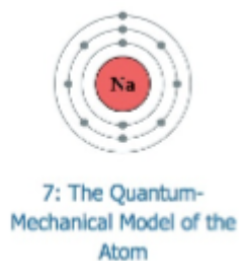


Figure 61 - Text: Chapter 7: The Quantum Mechanic Model of the Atom , by Libretext, CC BY-NC-SA 4.0 Author:Tro

2.8 Chapter 8: Periodic Properties of the Elements (CC BY-NC-SA 4.0)

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Figure 62 - Text: Chapter 8: Periodic Properties of the Elements, by Libretext, CC BY-NC-SA 4.0
Author:Tro

2.9 Chapter 9: Chemical Bonding I - Lewis Structure (CC BY-NC-SA 4.0)

[https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_A_Molecular_Approach_\(Tro\)/09%3A_Chemical_Bonding_I- Lewis Structures and Determining Molecular Shapes](https://chem.libretexts.org/Bookshelves/General_Chemistry/Map%3A_A_Molecular_Approach_(Tro)/09%3A_Chemical_Bonding_I- Lewis Structures and Determining Molecular Shapes)

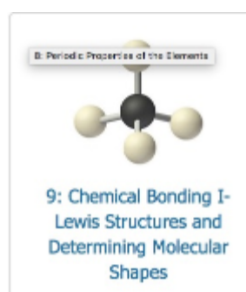


Figure 63 - Text: Chapter 9: Chemical Bonding I - Lewis Structure , by Libretext, CC BY-NC-SA 4.0
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2.10 Chapter 10: Chemical Bonding I - Valence Bond Theory and Molecular Orbital Theory (CC BY-NC-SA 4.0)

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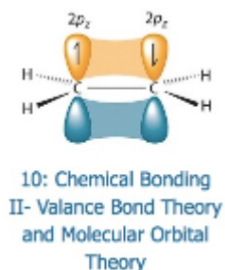


Figure 64 - Text: Chapter 10: Chemical Bonding I - Valence Bond Theory and Molecular Orbital Theory, by Libretext, CC BY-NC-SA 4.0
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2.11 Chapter 11: Liquids, Solids, and intermolecular forces (CC BY-NC-SA 4.0)

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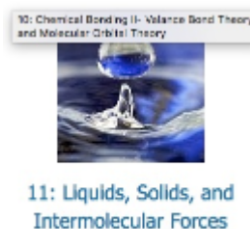


Figure 65 - Text: Chapter 11: Liquids, Solids, and intermolecular forces, by Libretext, CC BY-NC-SA 4.0 Author:Tro

2.12 Chapter 12: Solids and Modern Material (CC BY-NC-SA 4.0)

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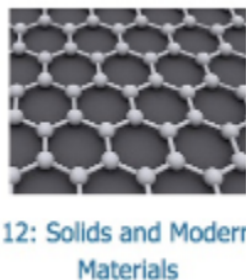


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2.13 Chapter 13: Solutions (CC BY-NC-SA 4.0)

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Figure 67 - Text: Chapter 13: Solutions , by Libretext, CC BY-NC-SA 4.0 Author:Tro

3. PhET Simulations

3.1 PhET Simulation: Atomic Interaction (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/atomic-interactions>

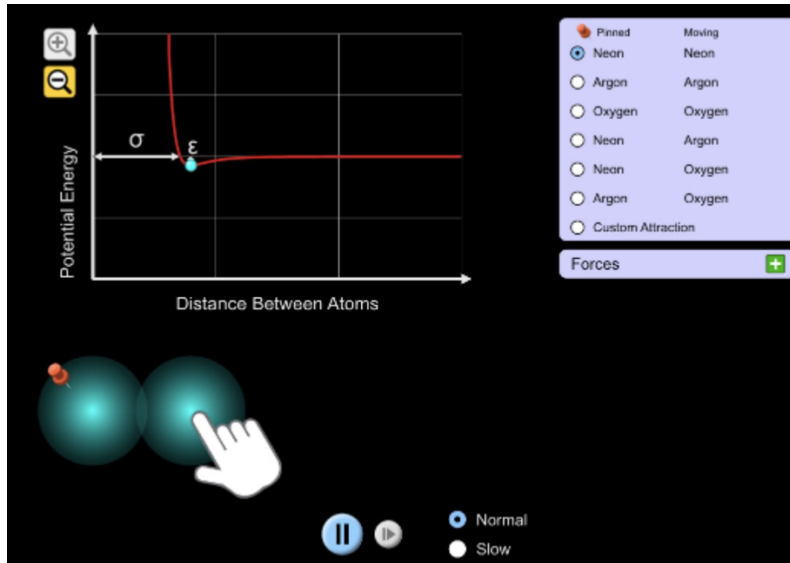


Figure 68 – Atomic interaction, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.2 PhET Simulation: Build a Nucleus (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/build-a-nucleus>



Figure 69 - Build a Nucleus, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.3 PhET Simulation: Density (CC BY 4.0 DEED)

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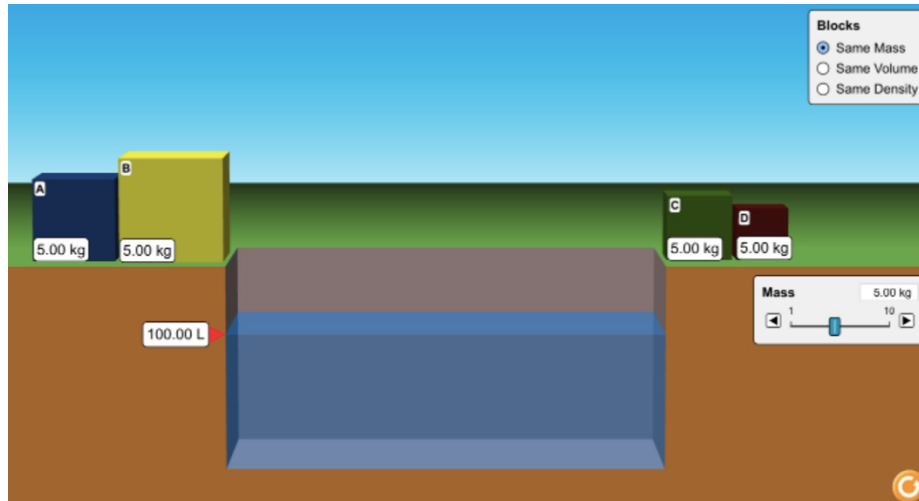


Figure 70 – Density, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.4 PhET Simulation: Normal Modes (CC BY 4.0 DEED)

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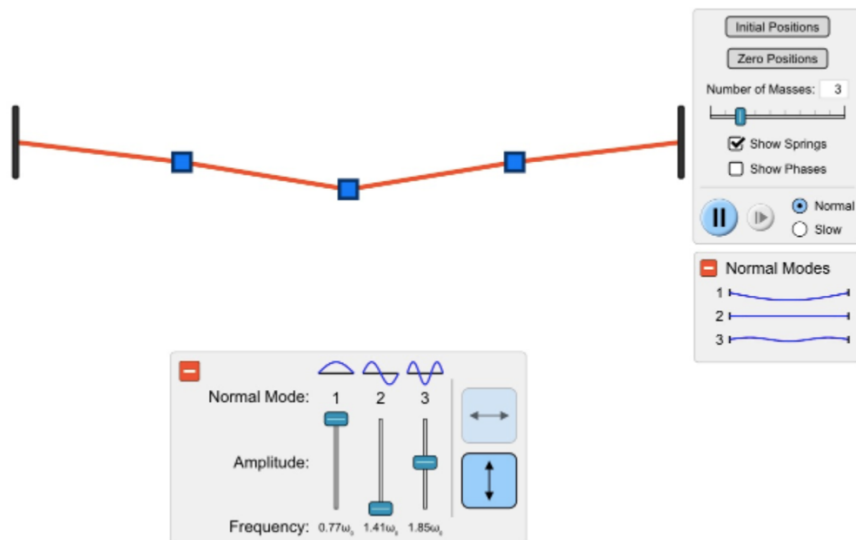


Figure 71 – Normal modes, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.5 PhET Simulation: Fourier Making Waves (CC BY 4.0 DEED)

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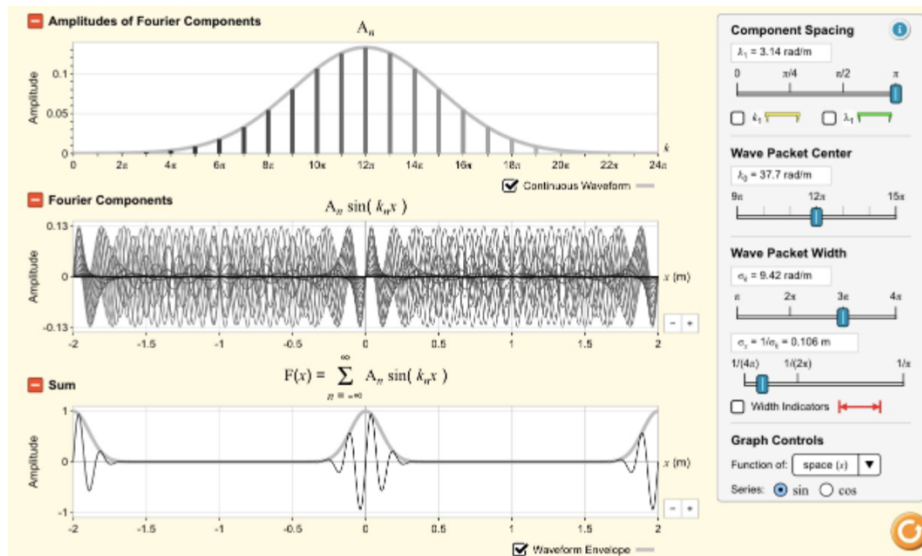


Figure 72 - Fourier Making Waves, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.6 PhET Simulation: Wave Interference (CC BY 4.0 DEED)

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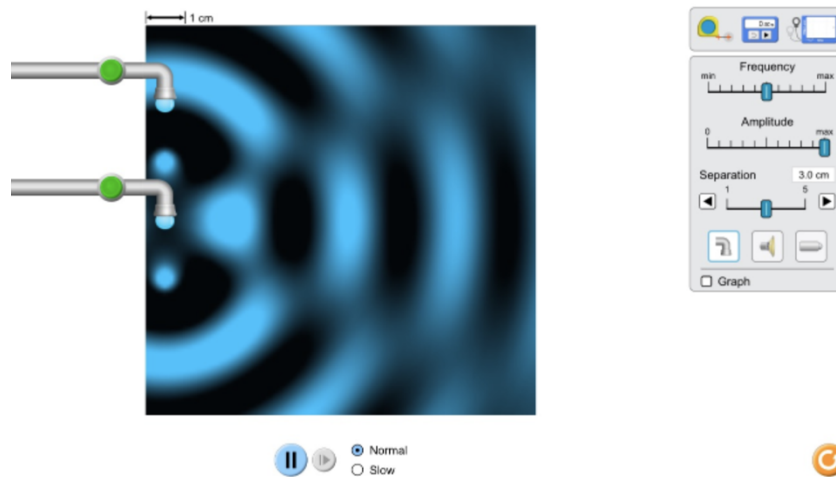


Figure 73 – Wave interference, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.7 PhET Simulation: collision-lab (CC BY 4.0 DEED)

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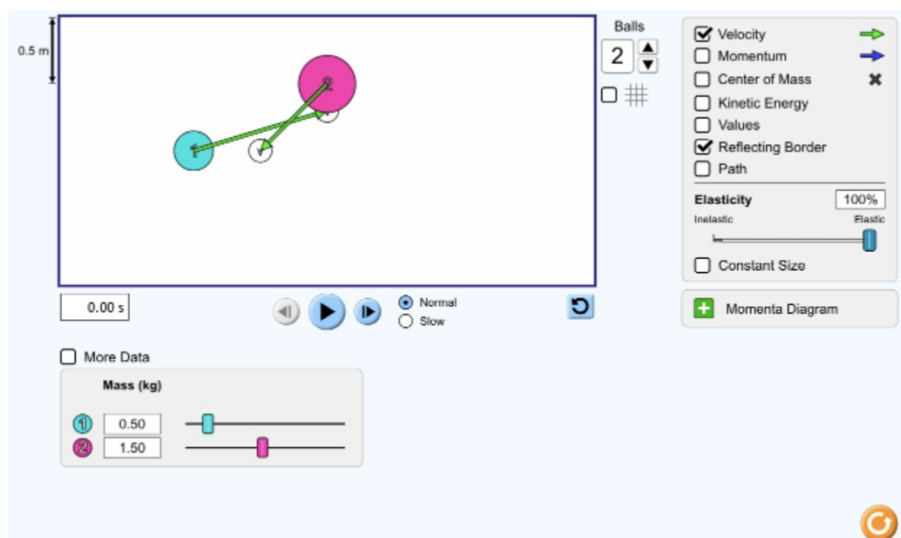


Figure 74 – Collision lab, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.8 PhET Simulation: build-a-molecule (CC BY 4.0 DEED)

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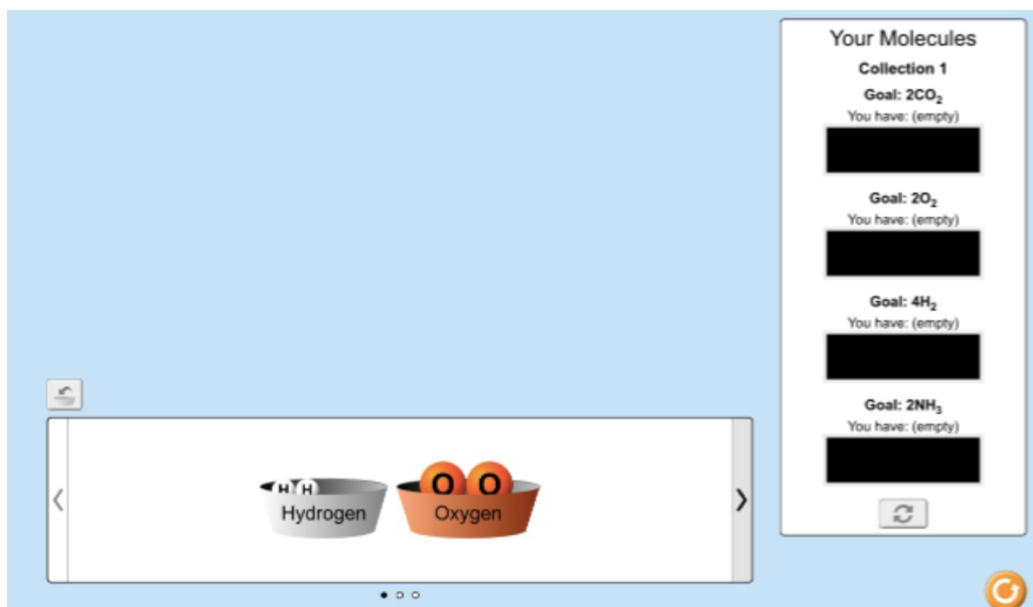


Figure 75 – Build a molecule, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.9 PhET Simulation: vector-addition (CC BY 4.0 DEED)

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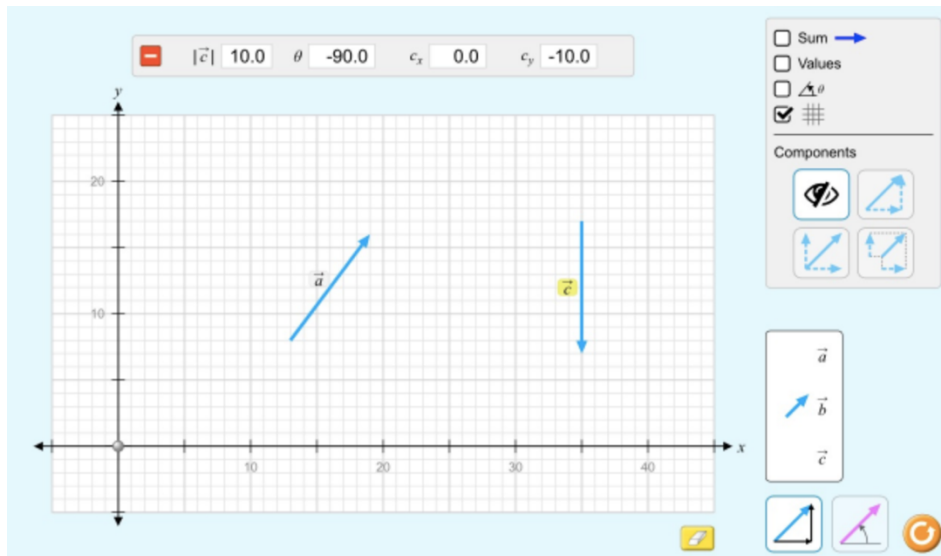


Figure 76 – Vector addition, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.10 PhET Simulation: curve-fitting (CC BY 4.0 DEED)

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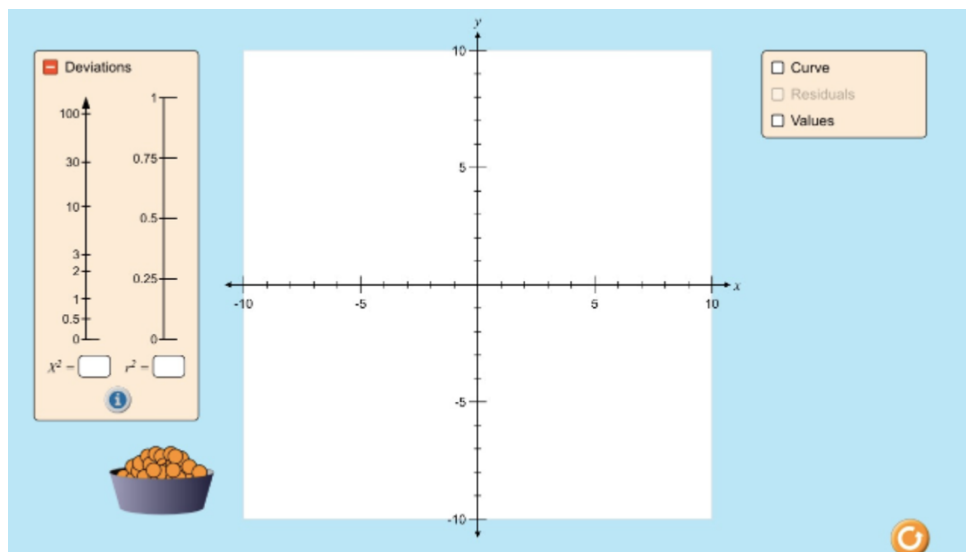


Figure 77 – Curve fitting, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.11 PhET Simulation: gravity-force-lab-basics (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/gravity-force-lab-basics>

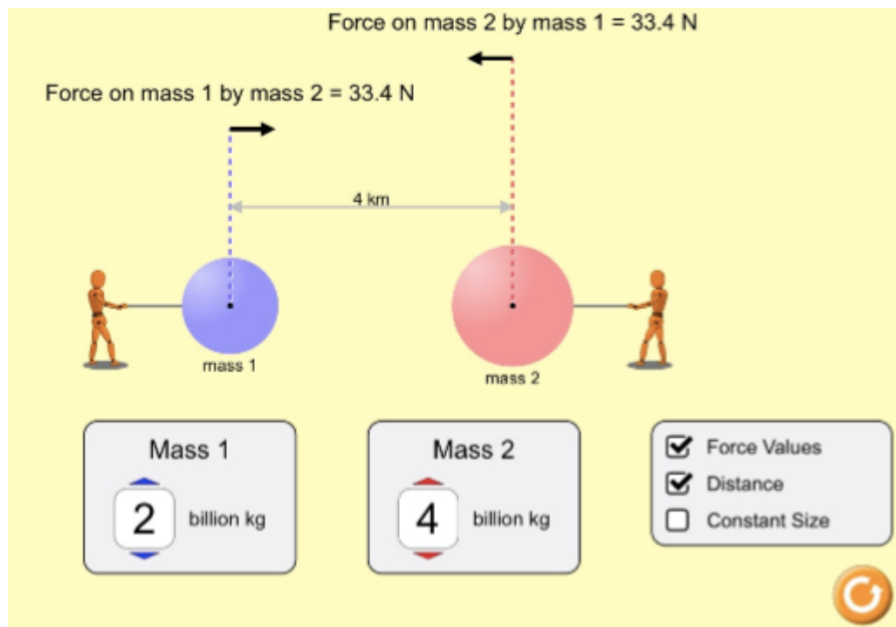


Figure 78 - gravity-force-lab-basics, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.12 PhET Simulation: waves-intro (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/waves-intro>

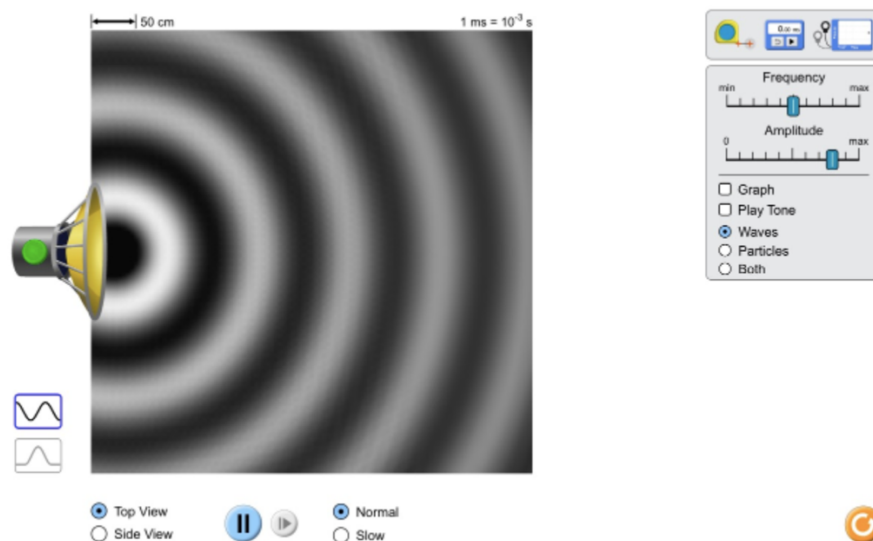


Figure 79 – Waves intro, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.13 PhET Simulation: diffusion (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/diffusion>

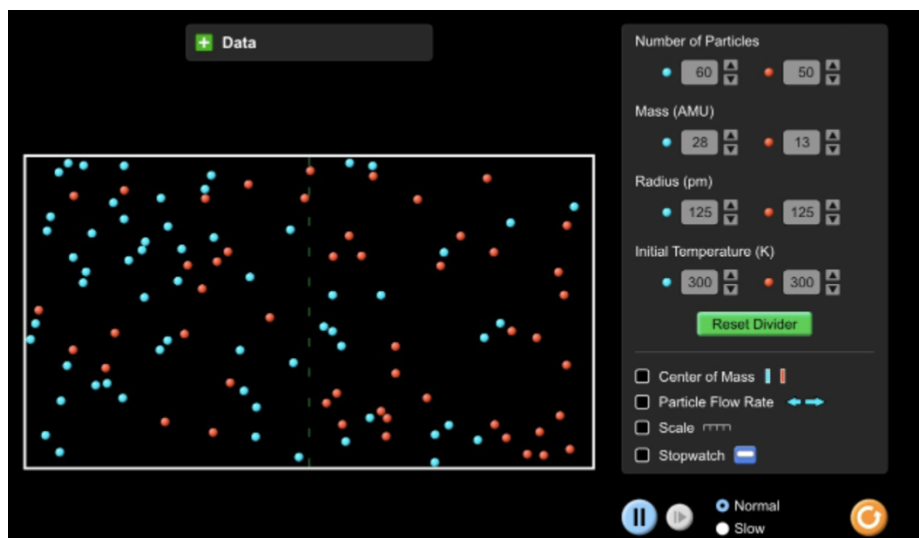


Figure 80 – Diffusion, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.14 PhET Simulation: gas-properties (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/gas-properties>

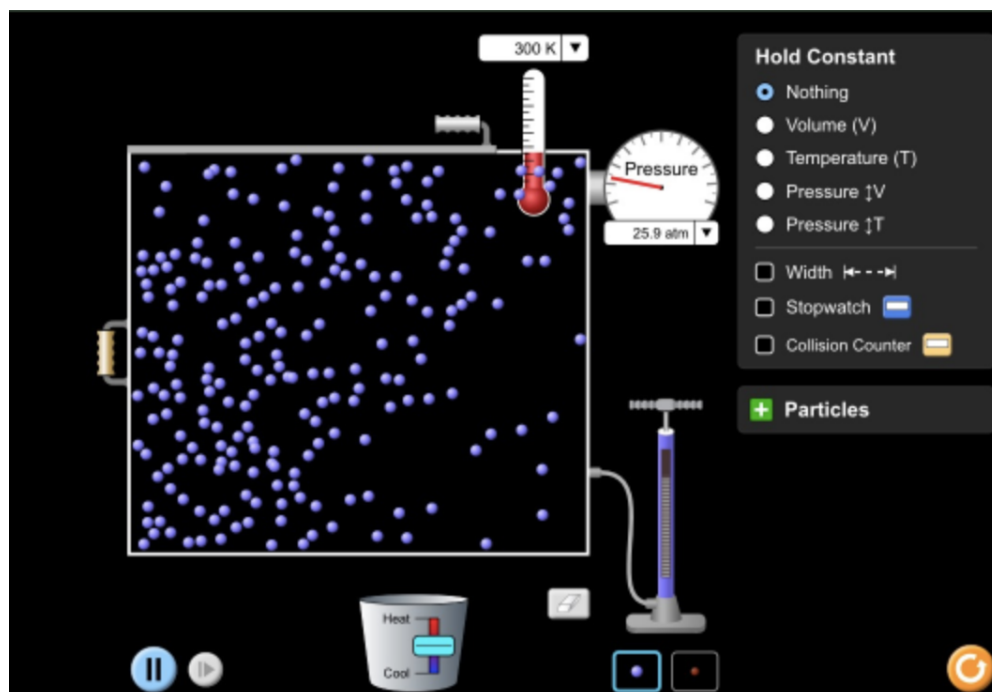


Figure 81 - gas-properties, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.15 PhET Simulation: energy-forms-and-changes (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/energy-forms-and-changes>

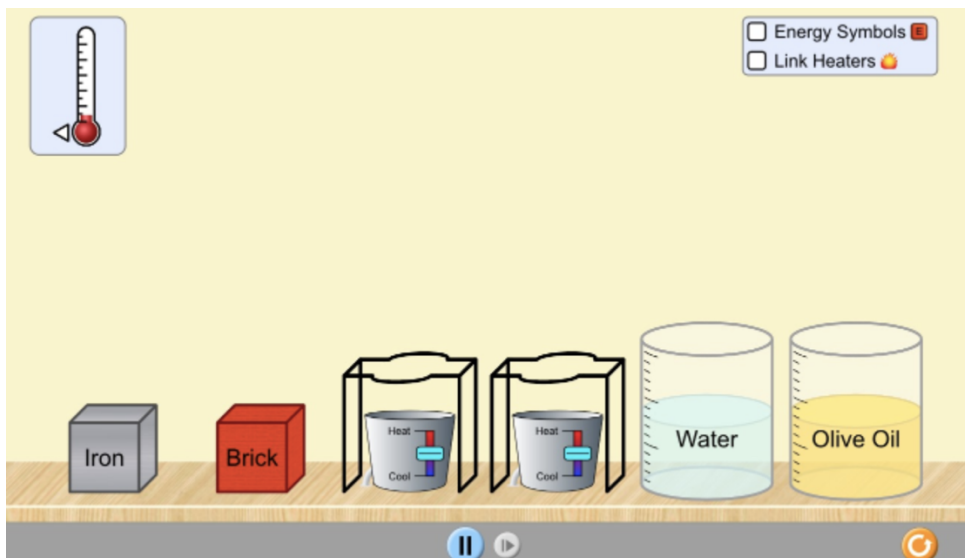


Figure 82 - energy-forms-and-changes, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.16 PhET Simulation: forces-and-motion-basics (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/forces-and-motion-basics>

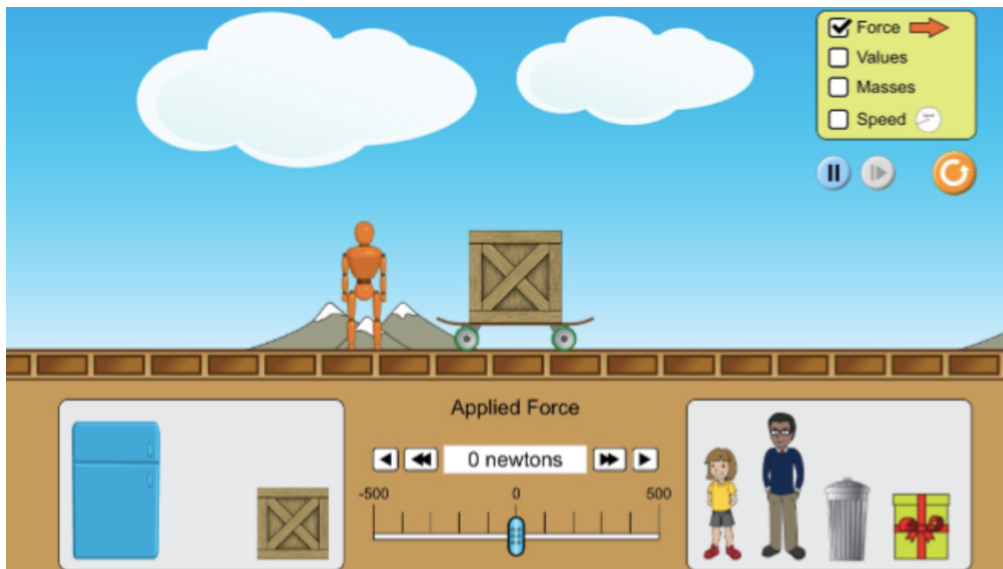


Figure 83 - forces-and-motion-basics, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.17 PhET Simulation: coulombs-law (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/coulombs-law>

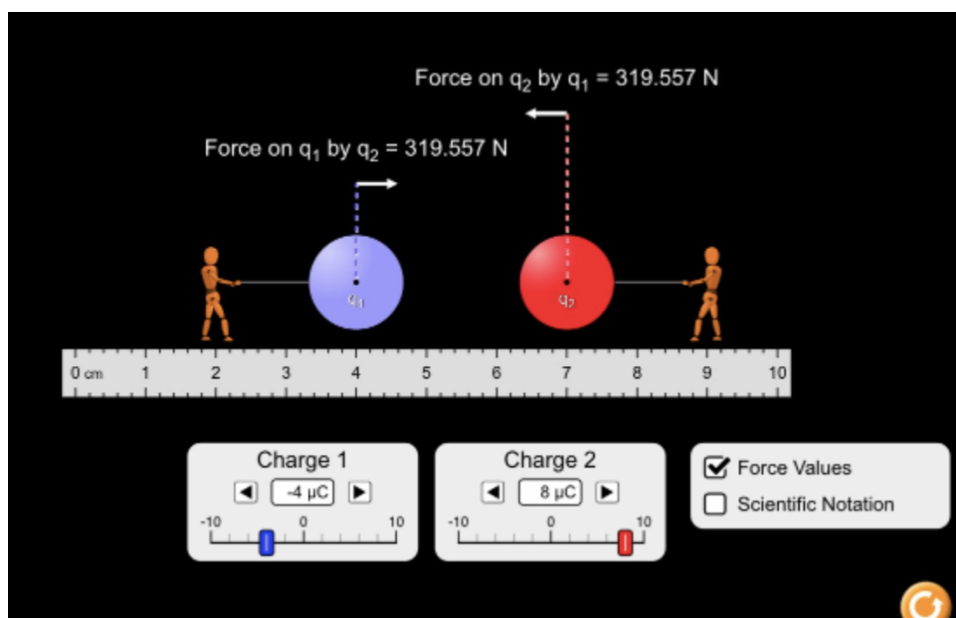


Figure 84 - coulombs-law, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.18 PhET Simulation: molecule-polarity (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/molecule-polarity>

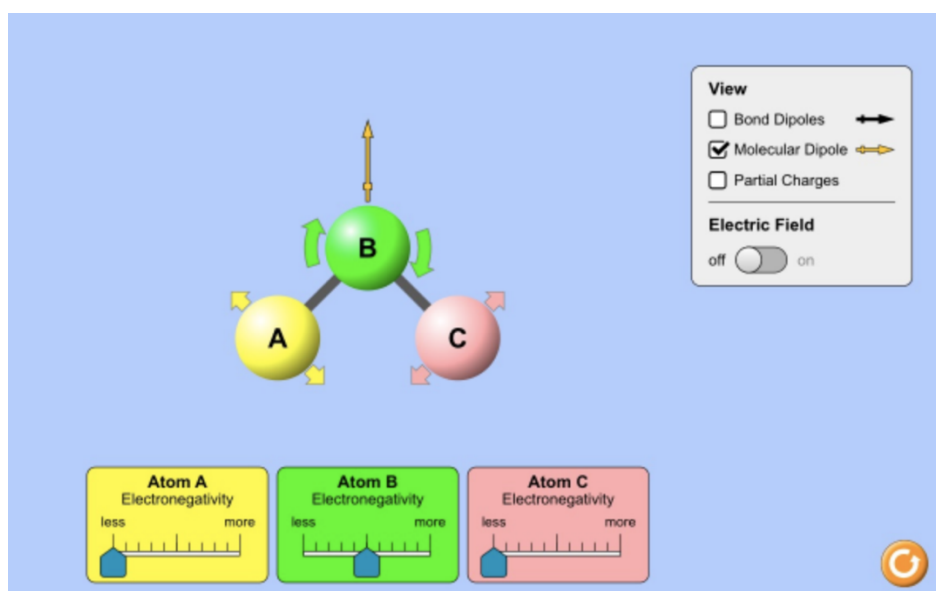


Figure 85 - molecule-polarity, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.19 PhET Simulation: states-of-matter-basics (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/states-of-matter-basics>

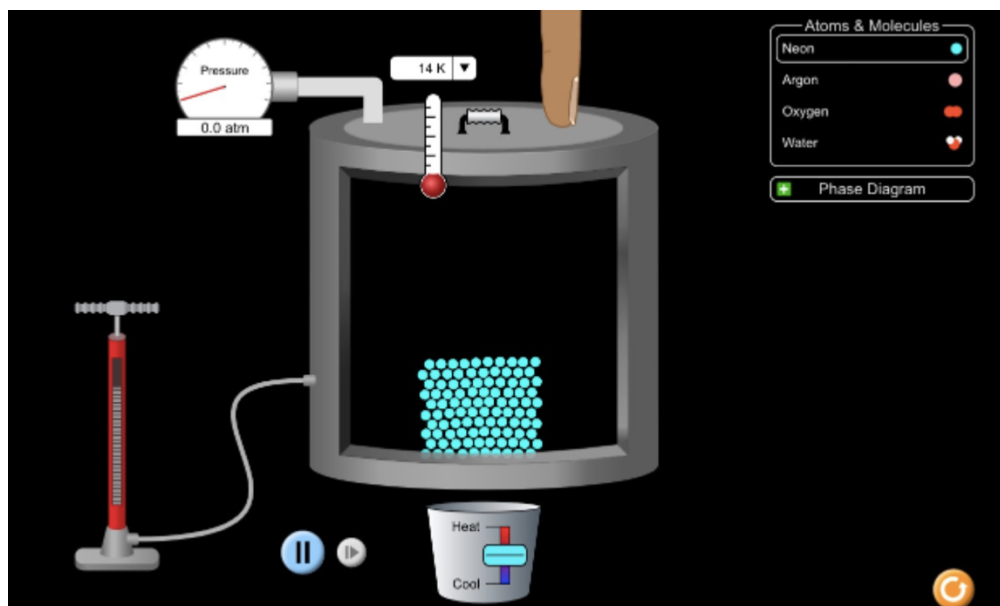


Figure 86 - states-of-matter-basics, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.20 PhET Simulation: states-of-matter (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/states-of-matter>

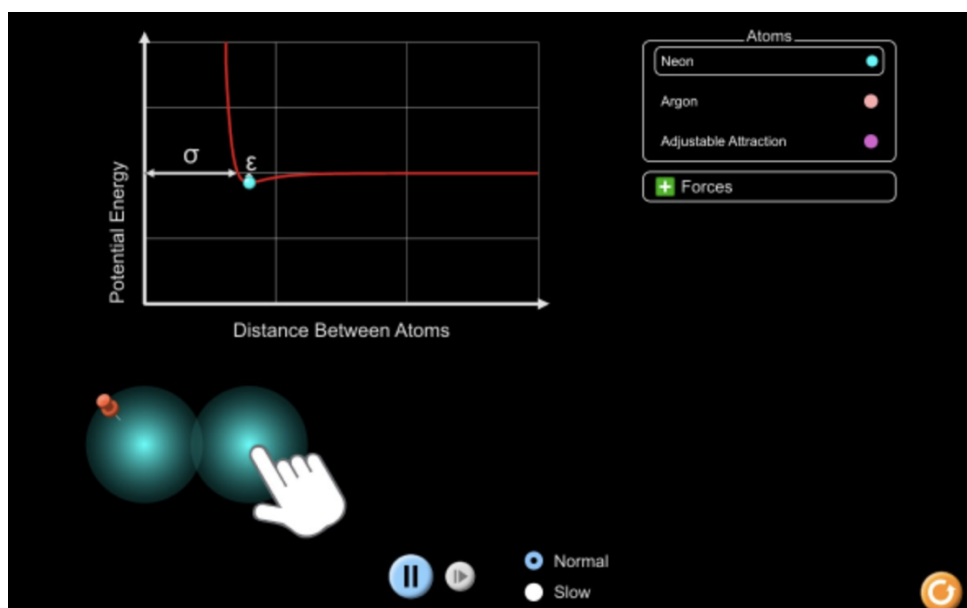


Figure 87 - states-of-matter, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.21 PhET Simulation: isotopes-and-atomic-mass (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/isotopes-and-atomic-mass>

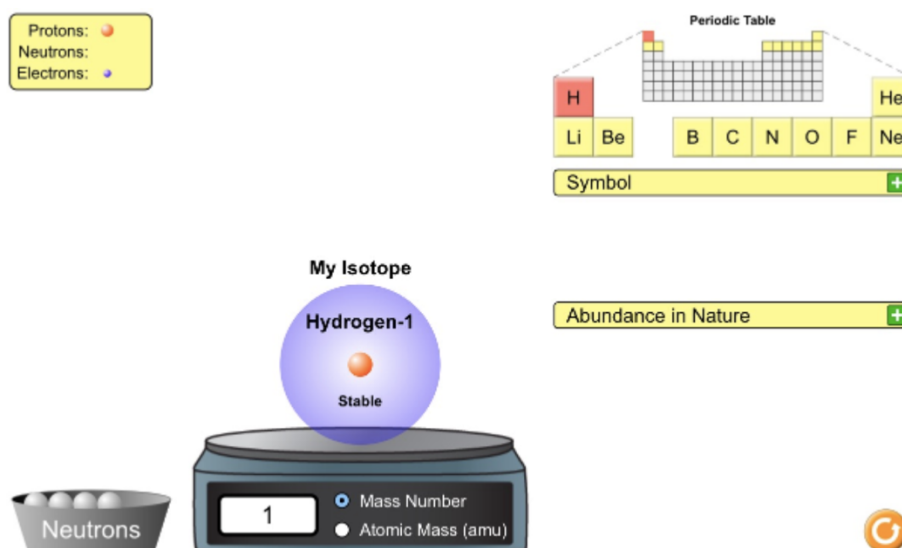


Figure 88 - isotopes-and-atomic-mass, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.22 PhET Simulation: molecule-shapes (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/molecule-shapes>

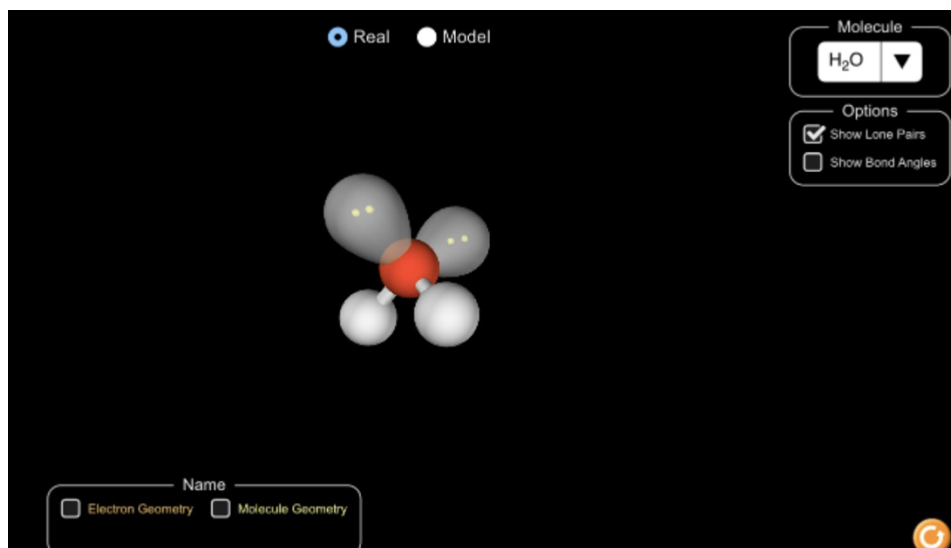


Figure 89 - molecule-shapes, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.23 PhET Simulation: molecule-shapes-basics (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/molecule-shapes-basics>

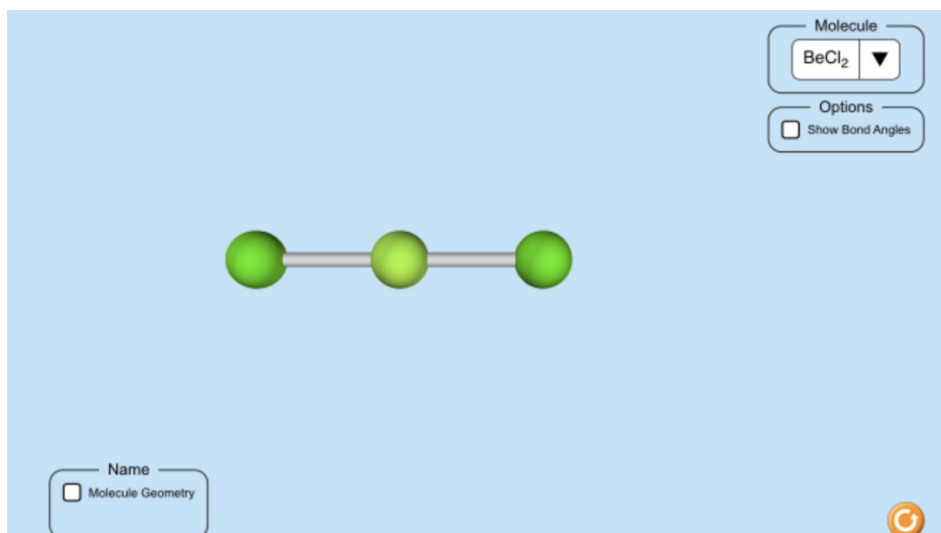


Figure 90 - molecule-shapes-basics, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.24 PhET Simulation: molecules-and-light (CC BY 4.0 DEED)

https://phet.colorado.edu/sims/html/molecules-and-light/latest/molecules-and-light_all.html

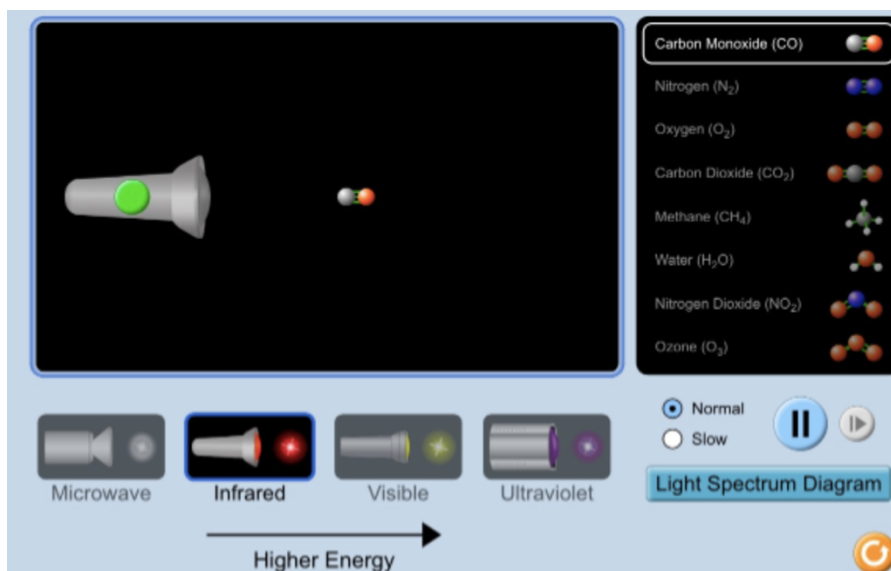


Figure 91 - molecules-and-light, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.25 PhET Simulation: reactants-products-and-leftovers (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/reactants-products-and-leftovers>

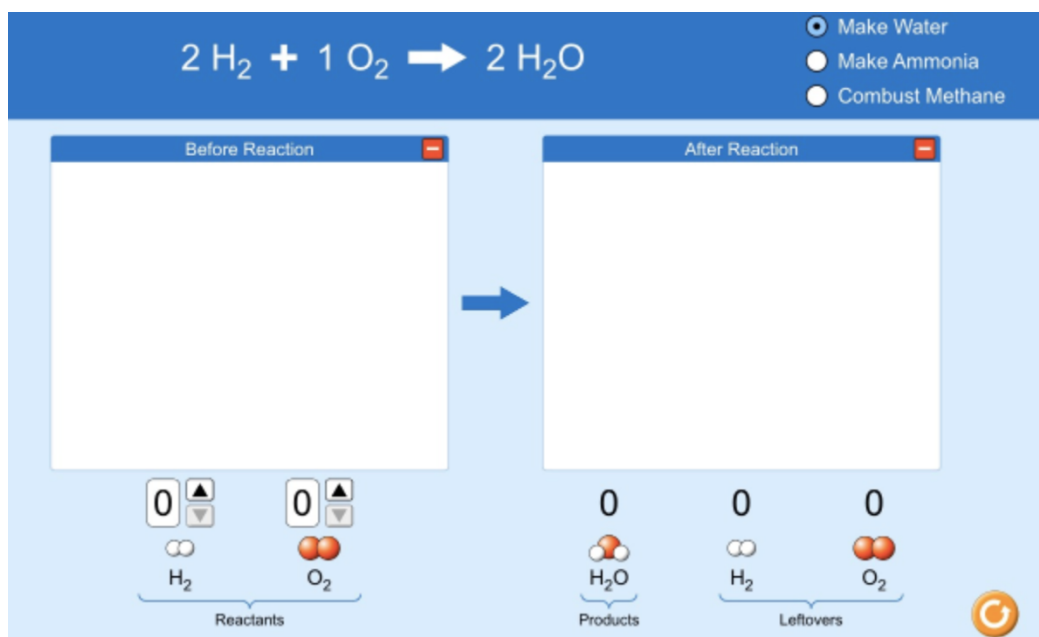


Figure 92 - reactants-products-and-leftovers, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.26 PhET Simulation: balancing-chemical-equations (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/balancing-chemical-equations>

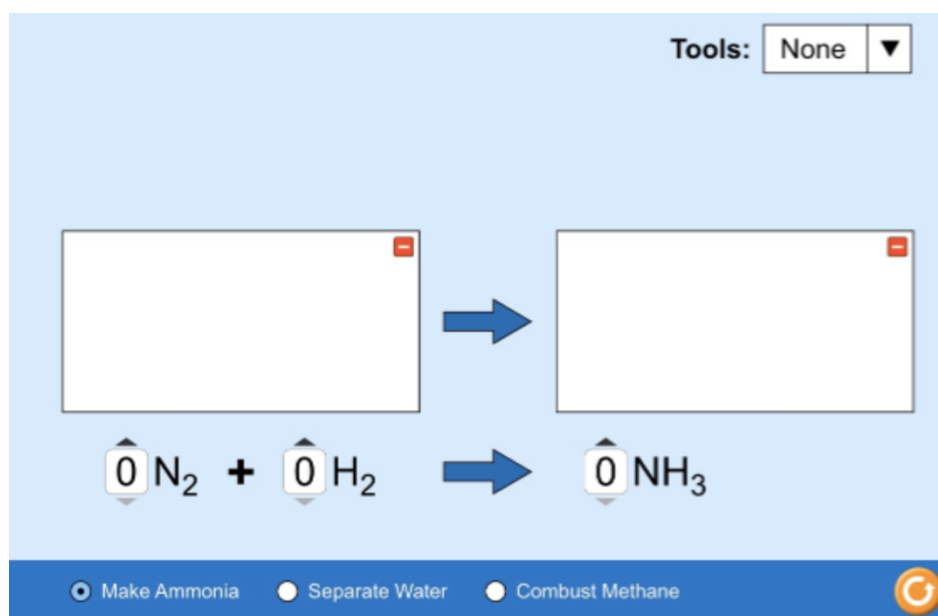


Figure 93 – Balancing Chemical Equations, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.27 PhET Simulation: ph-scale-basics (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/ph-scale-basics>

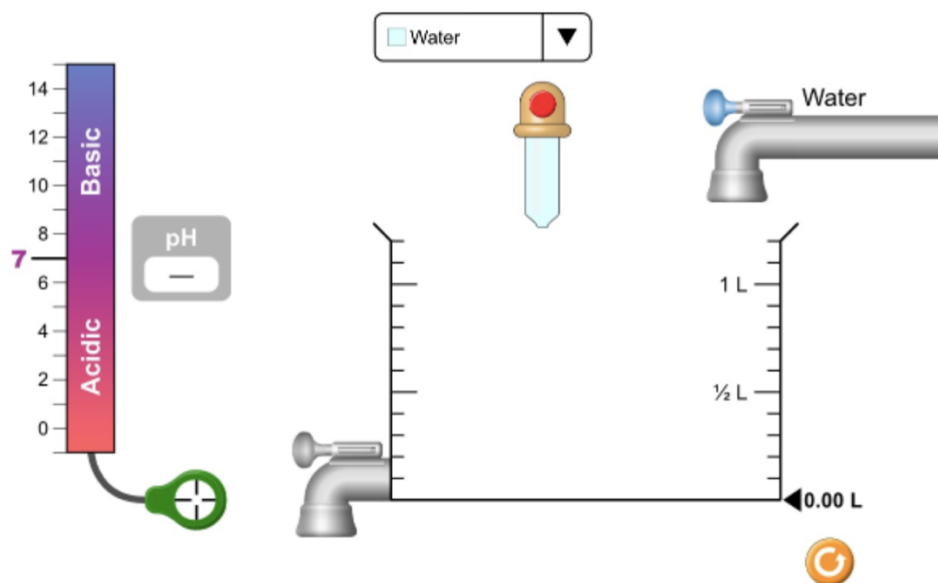


Figure 94 - ph-scale-basics, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.28 PhET Simulation: ph-scale-basics (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/ph-scale>

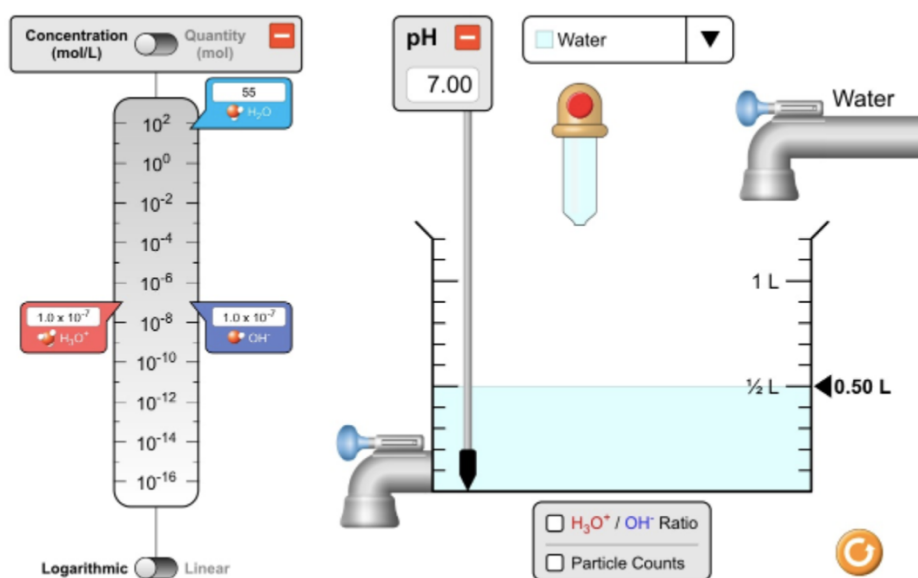


Figure 95 - pH-scale-basics, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.29 PhET Simulation: acid-base-solutions (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/acid-base-solutions>

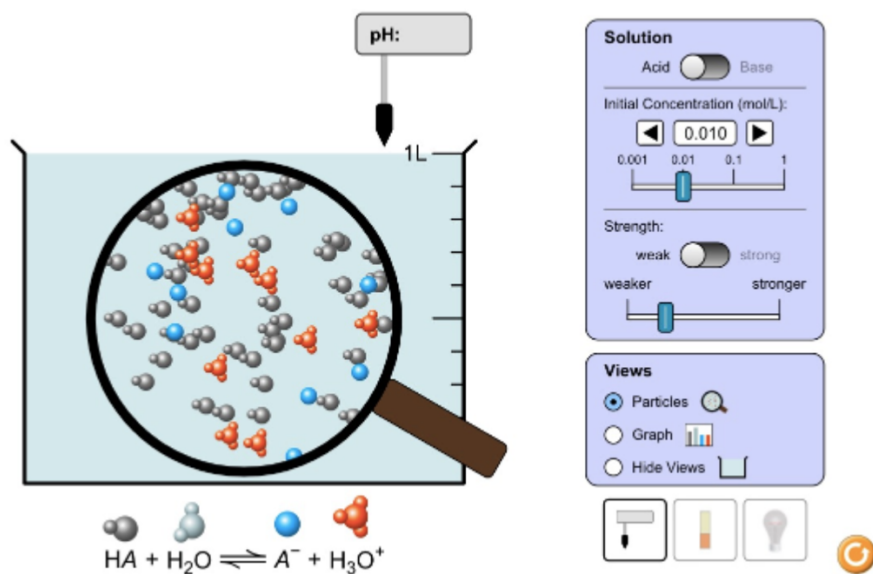


Figure 96 - acid-base-solutions, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.30 PhET Simulation: concentration (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/concentration>

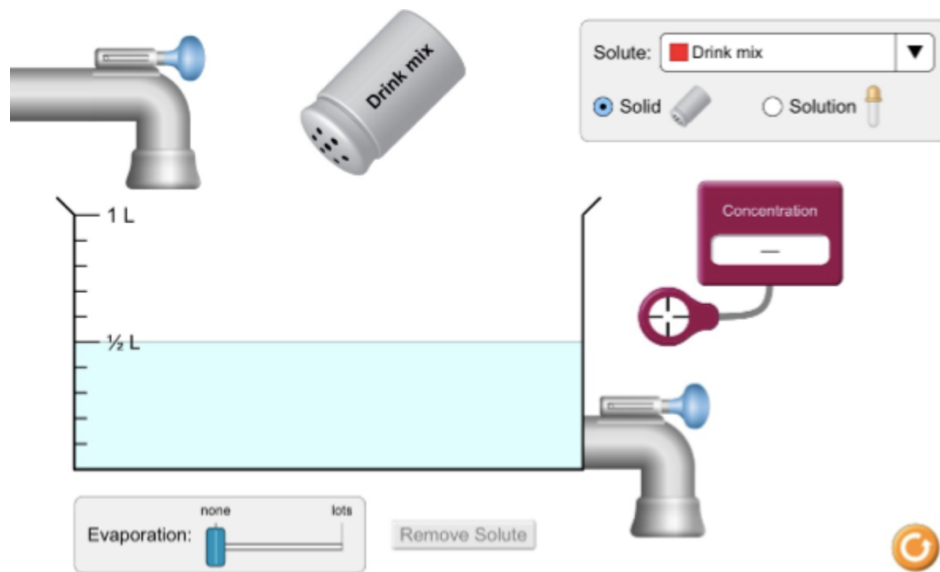


Figure 97 – Concentration, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.31 PhET Simulation: molarity (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/molarity>

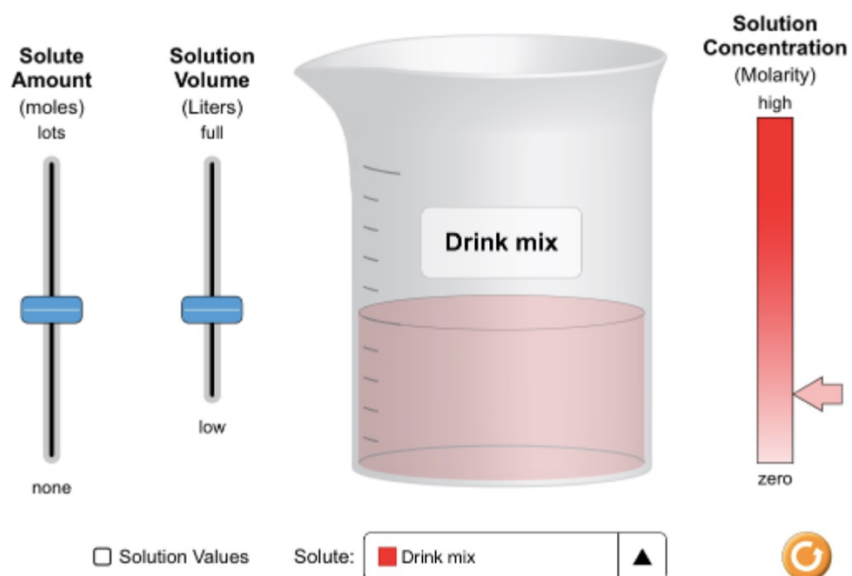


Figure 98 – Molarity, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

3.32 PhET Simulation: Build an atom (CC BY 4.0 DEED)

<https://phet.colorado.edu/en/simulations/build-an-atom>

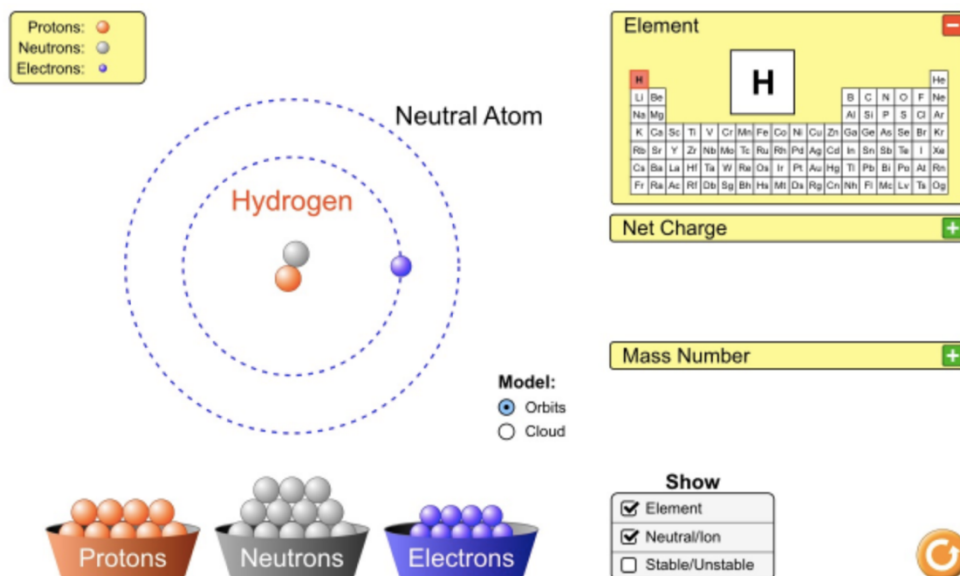


Figure 99 - Build an atom, Simulation by PhET Interactive Simulations, University of Colorado Boulder, licensed under CC-BY-4.0 (<https://phet.colorado.edu>).

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The creation of this work "OER-Based General Chemistry Content for Engineers" was supported by OpenCU Boulder 2023-2024, a grant funded by the Colorado Department of Higher Education with additional support from the CU Office of the President, CU Office of Academic Affairs, CU Boulder Office of the Provost, and CU Boulder University Libraries.