The Effect of Functionalization on Cation-Pi interaction

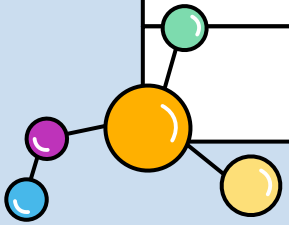
By: Dhyey Ray

TABLE OF CONTENTS

01

Background

Kumar Paper and Experimental Goals



Cation–p interactions in protein–ligand binding: theory and data-mining reveal different roles for lysine and arginine

Goal:

- Determine the interaction energy between benzene (model aromatic system) and the cationic amino acids lysine, arginine, and histidine.

Methods:

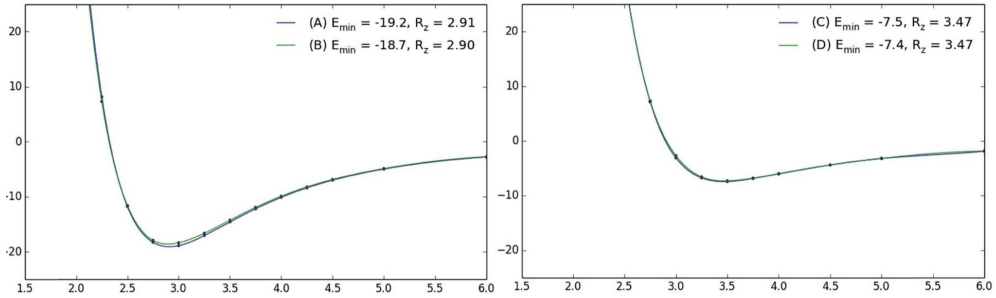
- Geometry Selection: Performed on benzene and cationic groups using MP2.
- Energy Calculations: Ground state interaction energies calculated using DLPNO-CCSD(T) in ORCA, with systematic variation of the cationic group position relative to benzene.
- Energy Decomposition: SAPT (via PSI4) used to break down interaction energies into components: exchange, induction, dispersion, and electrostatics.
- Solvent Effects: Interaction energies recalculated using dielectric constants to model solvent effects.

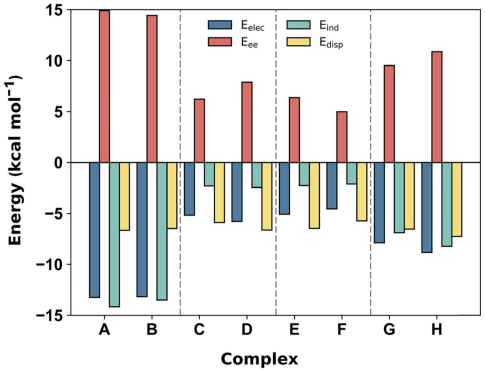
(A) (B) (C) (D)

Results

Results:

1. In the gas phase, lysine shows the strongest interaction with benzene due to dominant electrostatic forces than arginine's interaction, which is a balance of electrostatics and dispersion forces
2. Solvent effects (e.g., higher dielectric) weaken lysine's electrostatic interaction significantly, making it less favorable.
3. Empirical Protein Data Bank (PDB) data supports this trend, with arginine being more frequently involved in cation–π interactions than lysine.





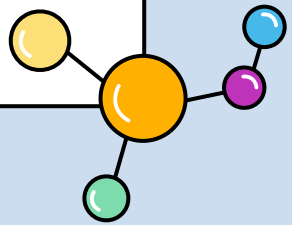
Our Experimental Goal

Let's see how functionalization of the benzene ring affects lysine-benzene interaction energy and how DFT and DLPNO-CCSD(T) compare in the analysis.

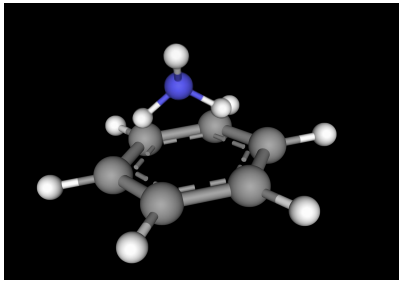
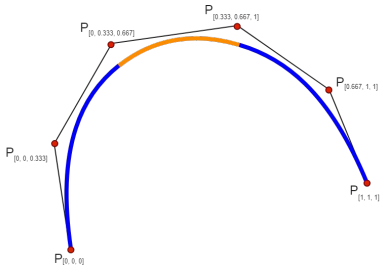
02

Methodology

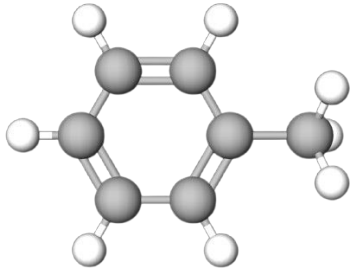
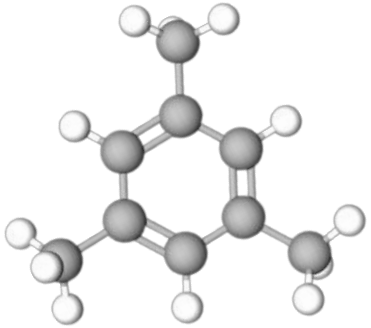
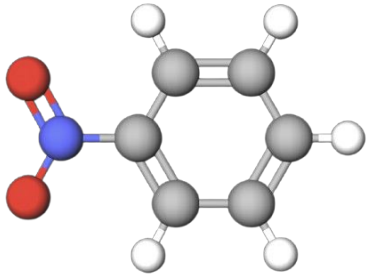
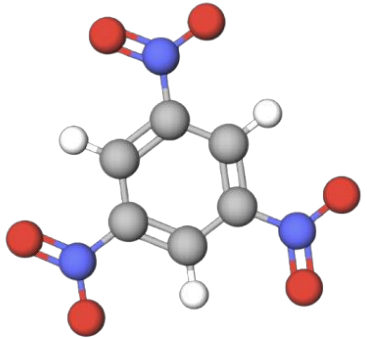
Python!!!



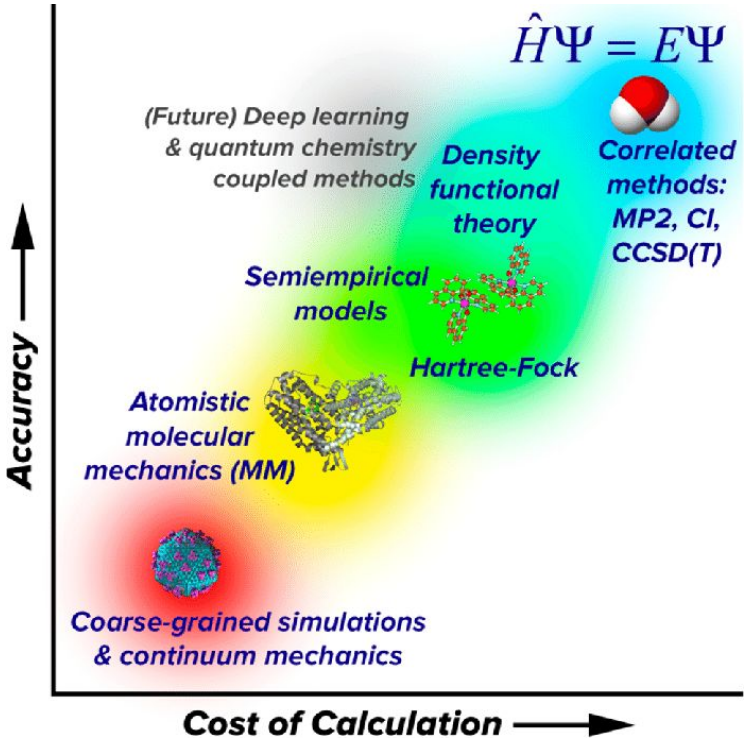
Steps

Optimized Structures	Preparation	Quantum Fun	Data Analysis
NIST National Institute of Standards and Technology U.S. Department of Commerce		$\hat{H}\Psi = E\Psi$ Hamiltonian Operator (Energy operator) Energy eigenvalue	
Obtain the optimized structure of the aromatic system from CCCBDB	Perform necessary rotations to align aromatic system and NH3 so that NH3 is in the center and atom aligned.	Run the optimization by lowering NH3 towards ring on Orca using DLPNO-CCSD(T) and DFT on PSI-4.	Create Graphs and find minima using Cubic Spline Interpolation.

Meet our Aromatic Systems and Predictions

	Toluene	1,3,5 Trimethyl Benzene	
	Nitrobenzene	1,3,5 Trinitro Benzene	

Computational Cost vs. Accuracy

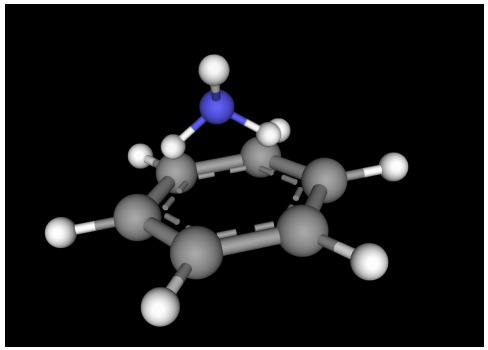


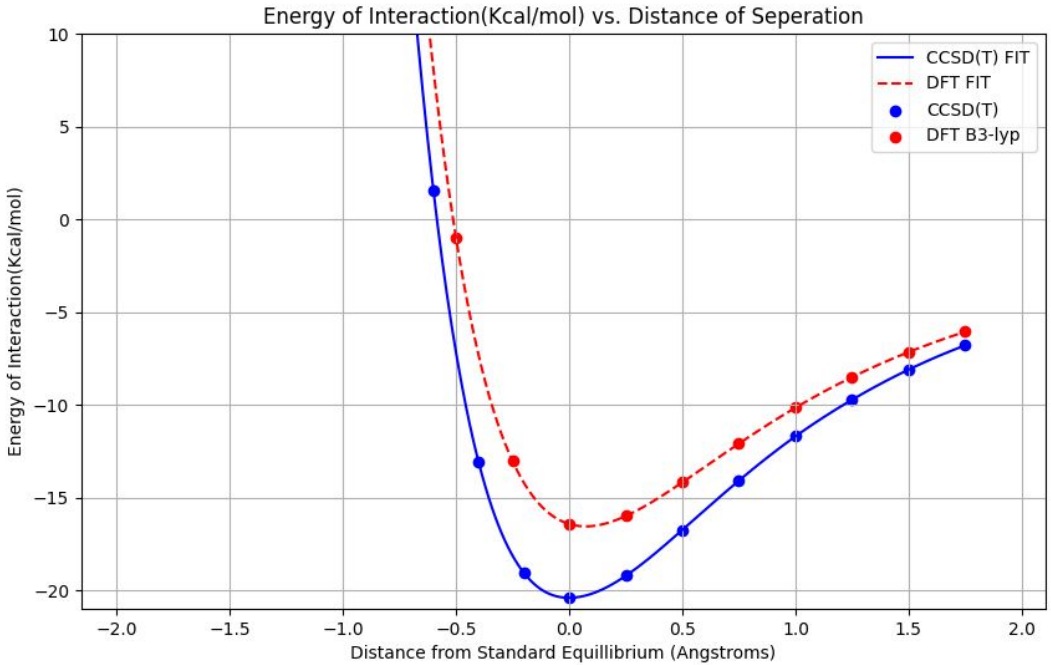
03

Results

Potential Energy Curves

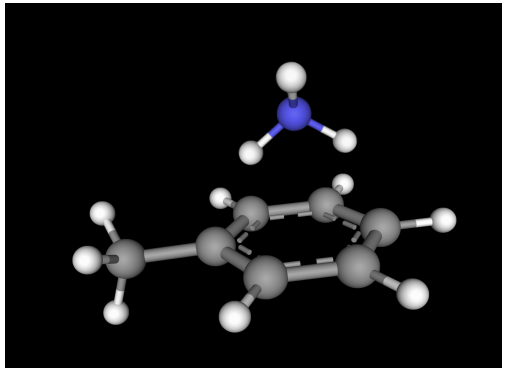
Lys/Benzene:

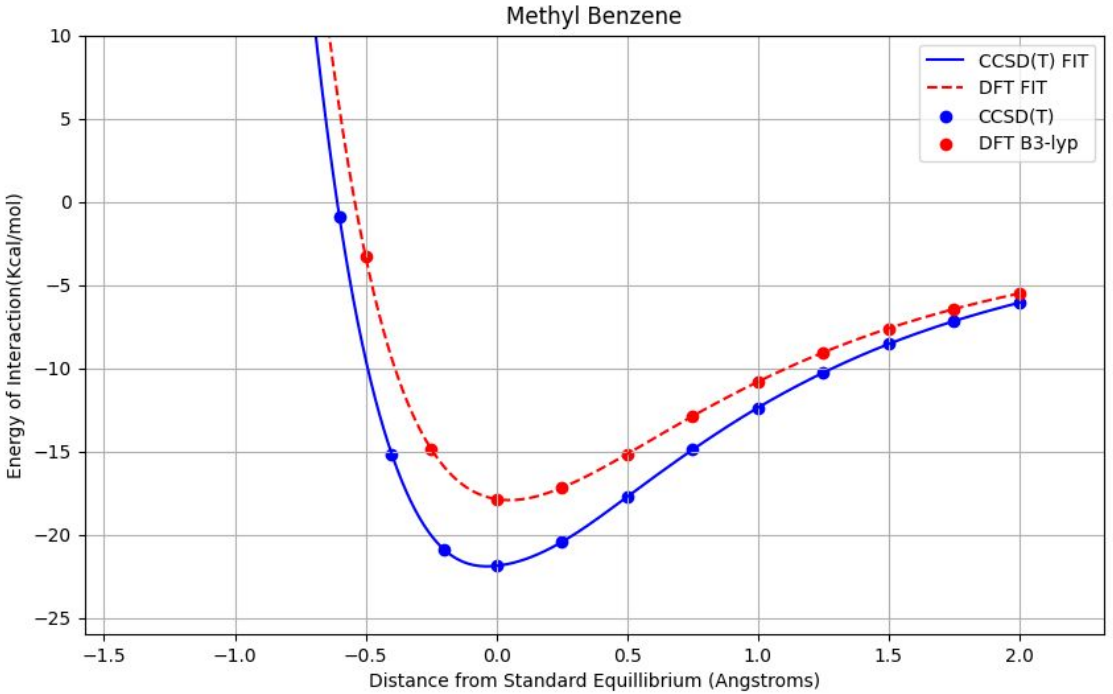




CCSD(T) minimum: x = -0.000100, y = -20.404561
DFT FIT minimum: x = 0.072645, y = -16.557487

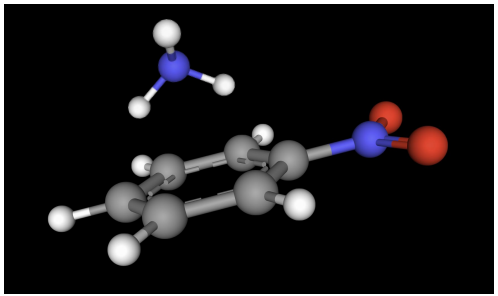
Lys/Toluene:

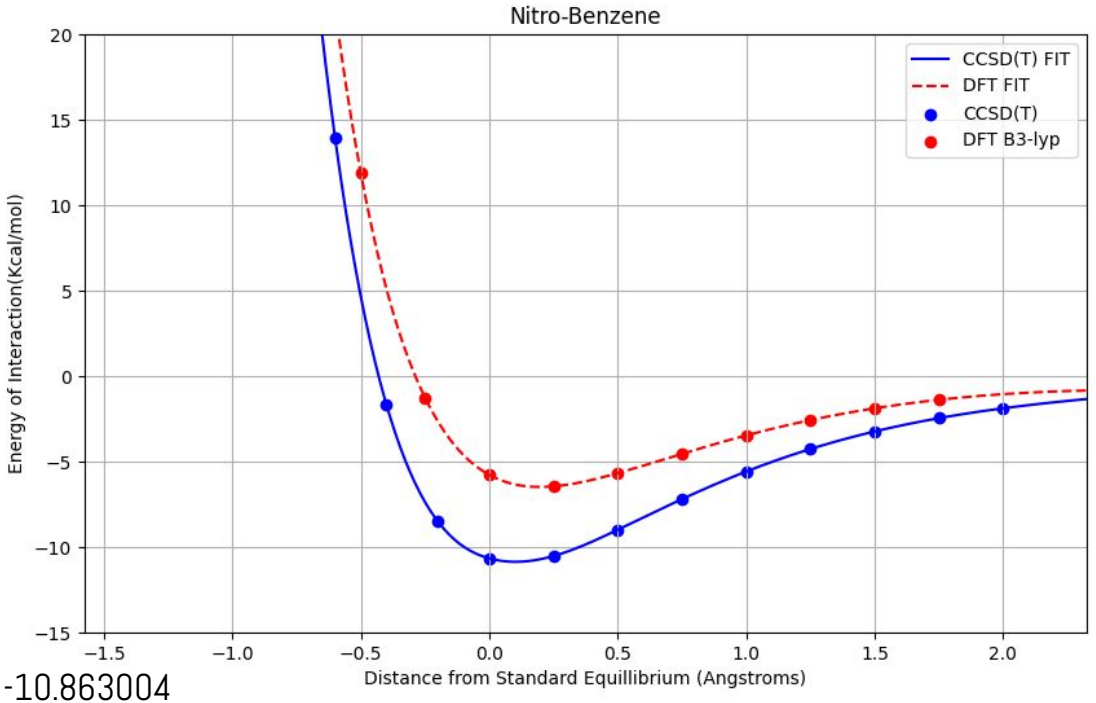




CCSD(T) minimum: x = -0.036874, y = -21.909502
DFT FIT minimum: x = 0.052605, y = -17.929000

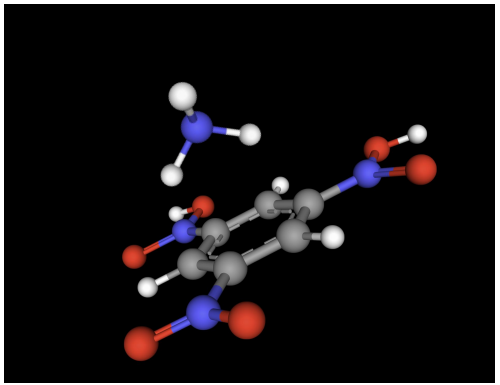
Nitro/Lys:

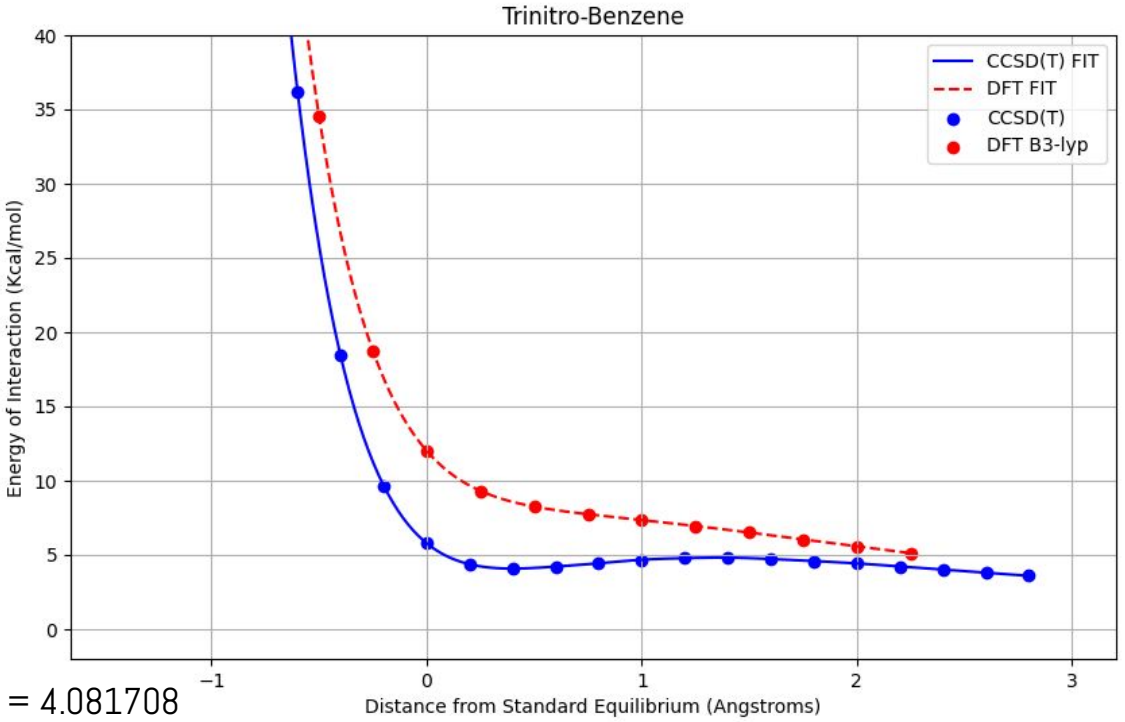




CCSD(T) minimum: x = 0.104609, y = -10.863004
DFT FIT minimum: x = 0.194890, y = -6.482986

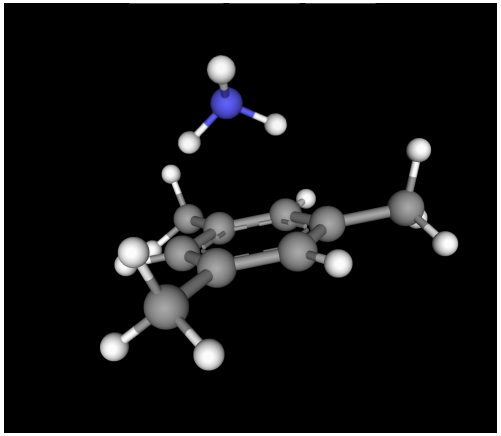
Trinitro/Lys:

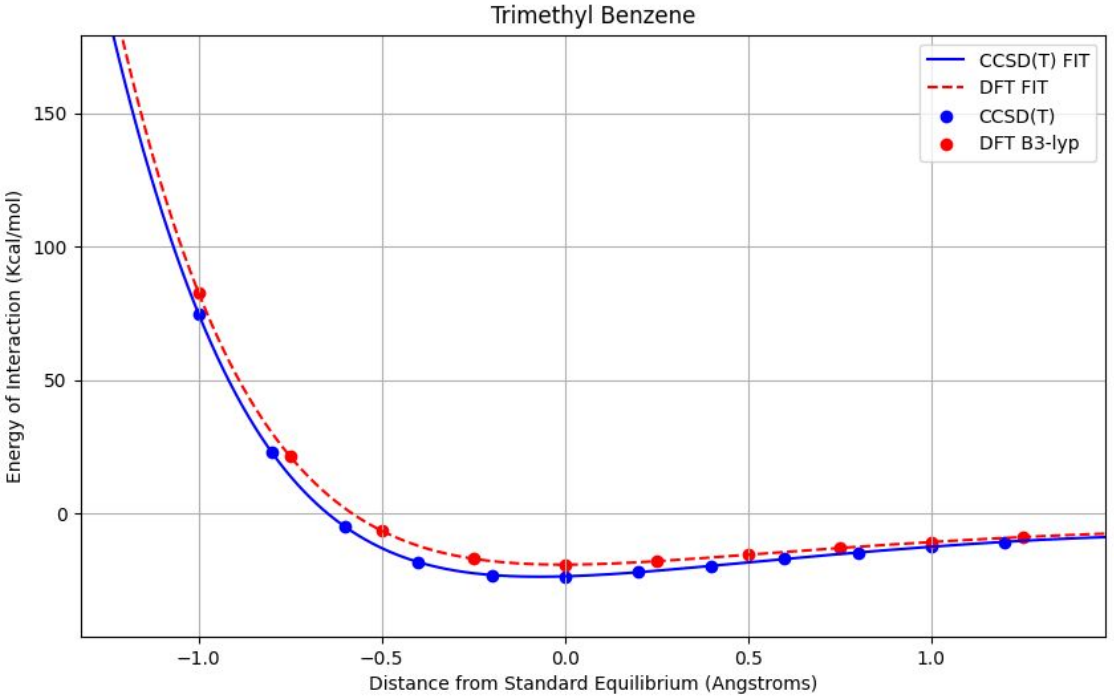




CCSD(T) minimum: x = 0.397595, y = 4.081708
DFT FIT minimum: x = 2.250000, y = 5.125369

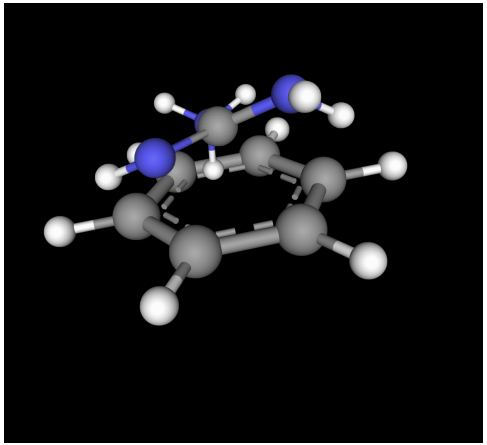
Trimethyl/Lys:

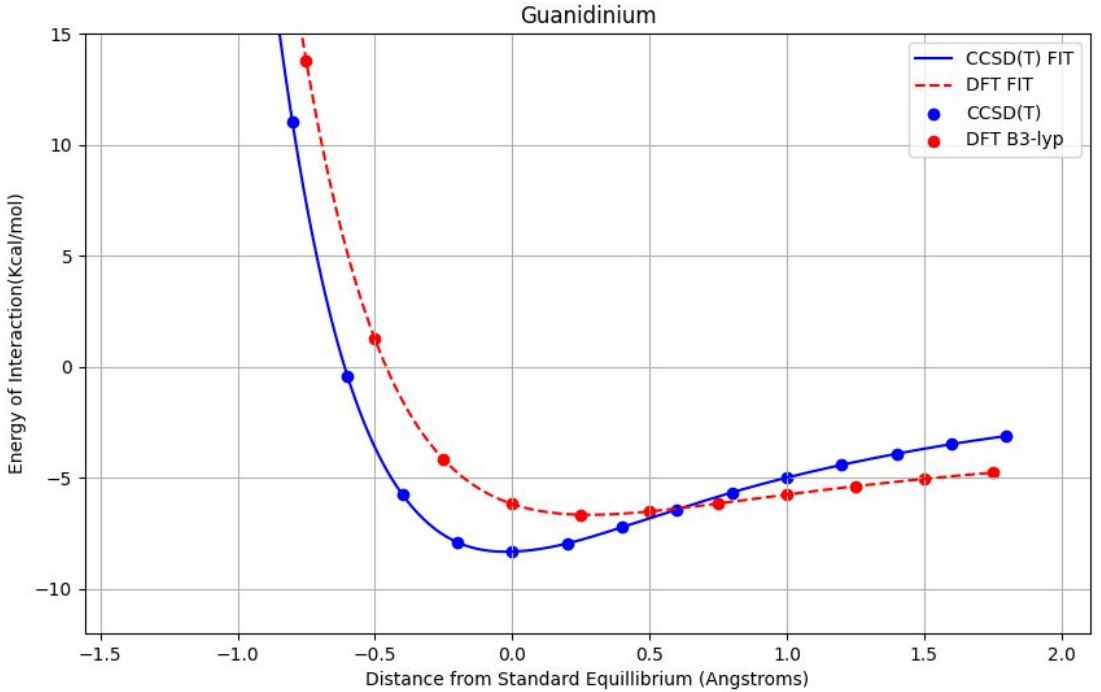




CCSD(T) minimum: x = -0.072545, y = -23.577745
DFT FIT minimum: x = -0.004509, y = -19.054448

Benzene/Arg:





CCSD(T) minimum: x = -0.023647, y = -8.328307
DFT FIT minimum: x = 0.283066, y = -6.666472

Summary

Data	Trinitro	Nitro	Benzene	Toluene	Trimethyl
Equilibrium Position Coupled Cluster(Å)	3.89	3.6	3.50	3.47	3.43
Equilibrium Position DFT (Å)	N/A	3.69	3.57	3.55	3.5
Interaction Energy Coupled Cluster(Kcal/mol)	-4.08	-10.86	-20.4	-21.9	-23.6
Interaction Energy DFT(Kcal/mol)	N/A	-6.48	-16.5	-17.9	-19

Computational Cost

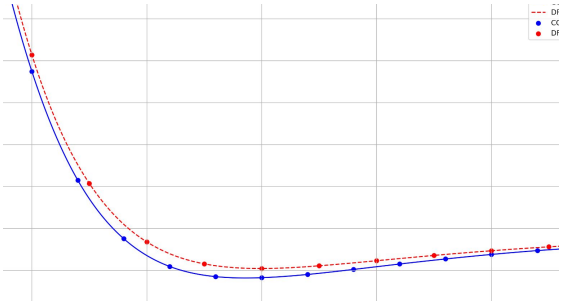
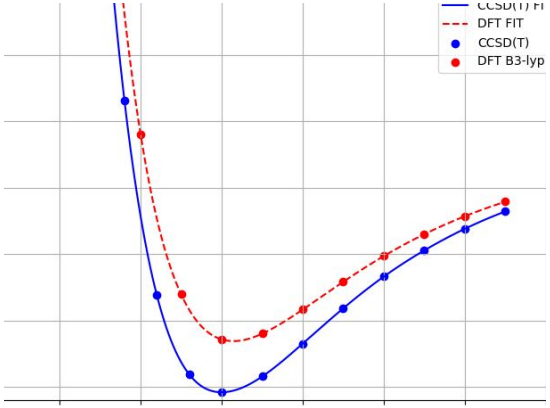
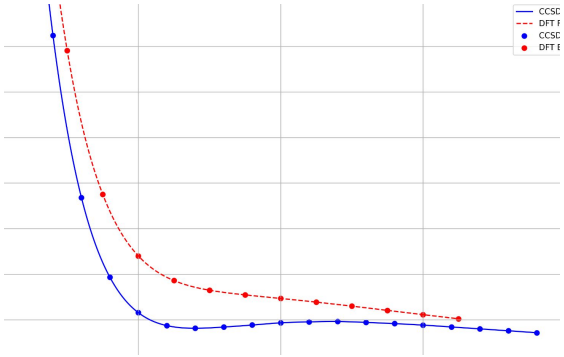
Name of Method	Trinitro	Trimethyl	Toluene	Nitro	Guanidinium
PSI4 DFT(Either Functional) 60 CPU Core	2:40	1:30	>1minute	>1minute	1.40
ORCA DLPNO CCSD(T) 60 CPU Core	18.30	15	11	6:42	5:47

04

Conclusion

Future Direction and Insights

Accuracy of DFT

Toluene	Benzene	Nitro-Benzene
		
Lots of Correlation High Accuracy	Normal Correlation Steepness Lowered	Low Correlation Wrong Shape

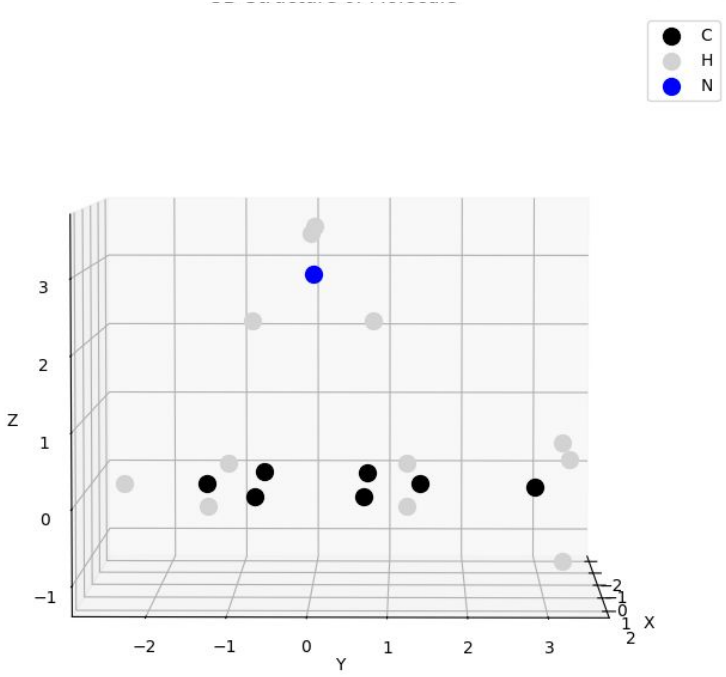
DFT (Density Functional Theory) vs. CCSD

The functionals in this study are LDA based, so they over correlate because they don't do well with non-smooth electron densities. This causes inaccuracies whereas Couple Cluster does a Hartree Fock then introduces an excitationa operation that accounts for single, double and in this case triple excitations, which encapsulates correlation more accurately. The first excitation account for orbital relaxation, the second excitation account for

$$\left[-\frac{\hbar^2}{2m}\nabla^2 + V_\mathrm{s}(\mathbf{r})\right]\varphi_i(\mathbf{r}) = \varepsilon_i\varphi_i(\mathbf{r} \qquad V_\mathrm{s}(\mathbf{r}) = V(\mathbf{r}) + \int \frac{n(\mathbf{r}')}{|\mathbf{r}-\mathbf{r}'|}\,\mathrm{d}^3\mathbf{r}' + V_\mathrm{XC}[n(\mathbf{r})],$$

$$\begin{aligned} |\Psi\rangle &= e^{\hat{T}}|\Phi_0\rangle \\ &= \left(1 + \hat{T} + \frac{1}{2}\hat{T}^2 + \frac{1}{3!}\hat{T}^3 + \cdots\right)|\Phi_0\rangle, \end{aligned}$$

Optimization of Uneven Functionalizations



1. Free Geometry Minimization of the unsymmetrical aromatic complexes using DFT B3LYP
2. Finding the energy of the complex, and individual molecules using CCSD(T)

Future Directions

1.Compute potential energy surfaces for (Arg/Lys–Phe/Tyr) with solvent effects.

2. Compute potential energy surfaces for (Phe/Tyr–Phe/Tyr) with solvent effects.

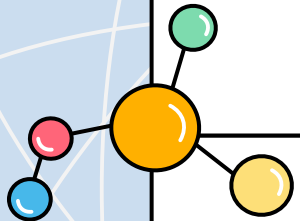
3. Parametrize a Coarse grain model with PEC data

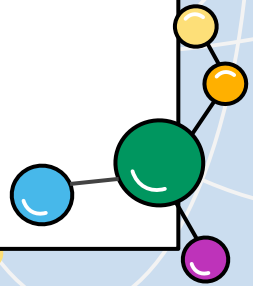
Citation

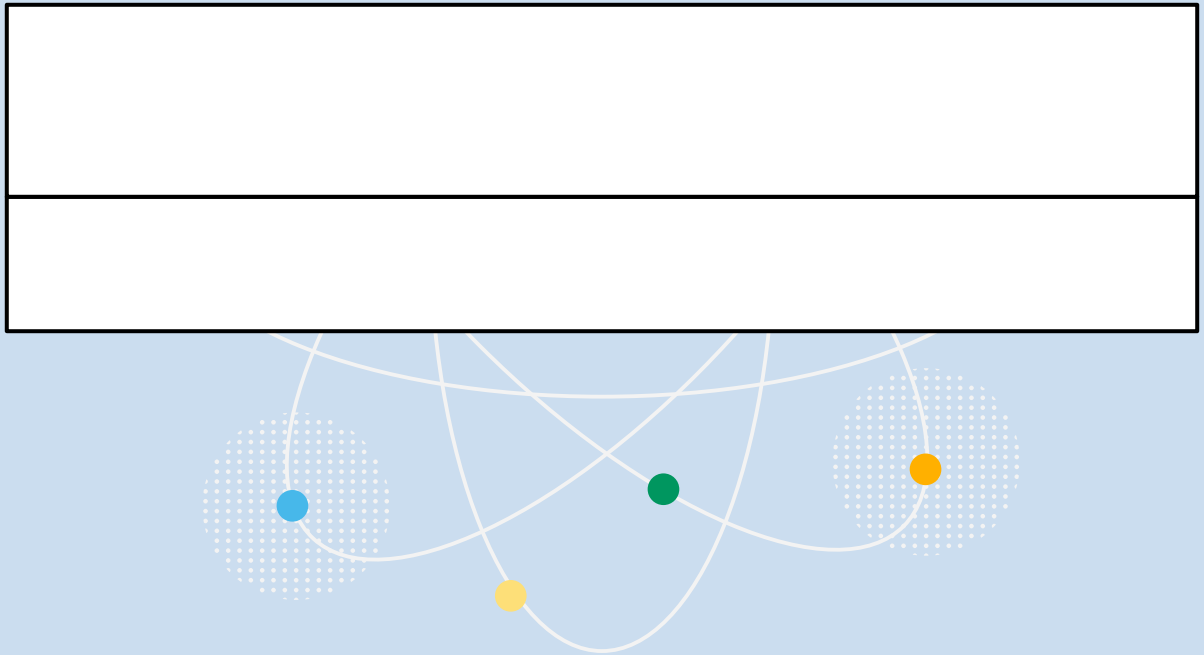
Kiran Kumar, M. Woo, S., Thomas Siu, A. Cortopassi, W., Fernanda Duarte, & S. Paton, R. (2018, January 31). *Cation–π interactions in protein–ligand binding: Theory and data-mining reveal different roles for lysine and arginine*. Chemical Science. https://pubs.rsc.org/en/content/articlehtml/2018/sc/c7sc04905f

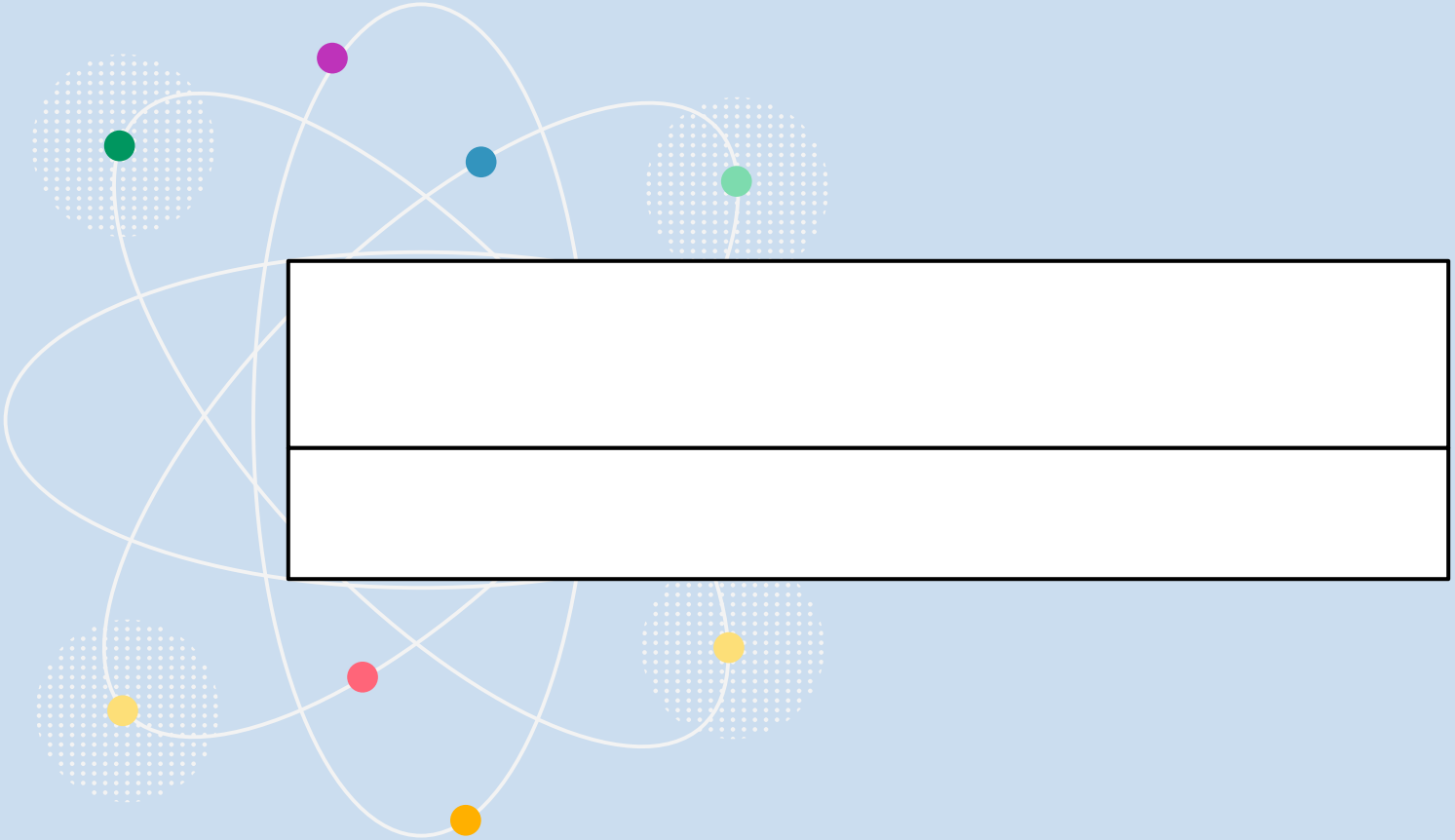
THANKS

Questions? Comments? Suggestions?





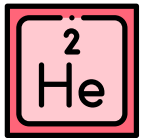




TWO COLUMNS

HYDROGEN

Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon



HELIUM

Venus has a beautiful name and is the second planet from the Sun. It's hot and has a poisonous atmosphere

THE STRUCTURE OF THE ATOM: CARBON ATOM

ELECTRON

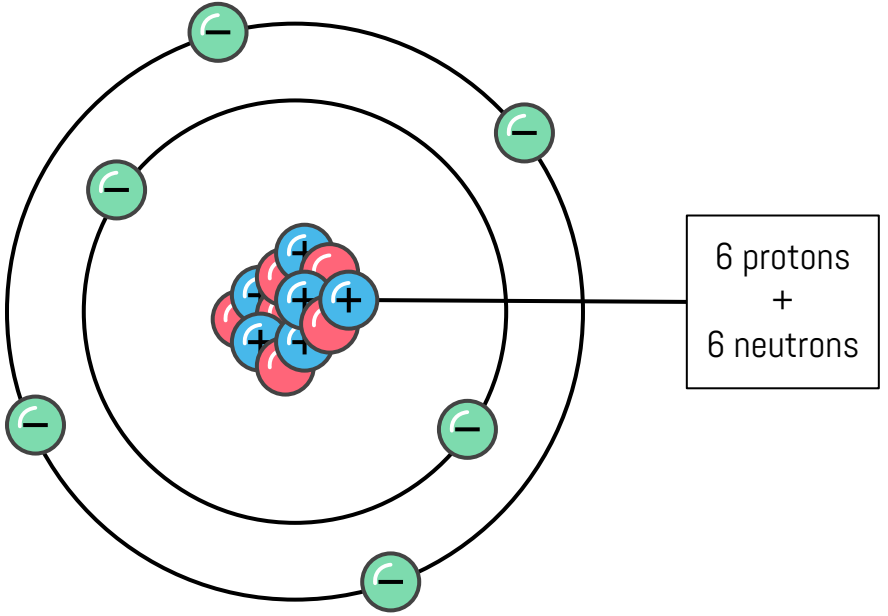
Mercury is the closest planet to the Sun

PROTON

Venus is the second planet from the sun

NEUTRON

Despite being red, Mars is a cold place



TWO COLUMNS

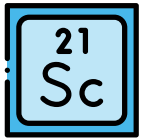
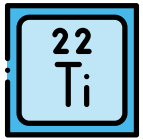
LITHIUM

Mercury is the closest planet to the Sun and the smallest one in the Solar System—it's only a bit larger than the Moon

BERYLLIUM

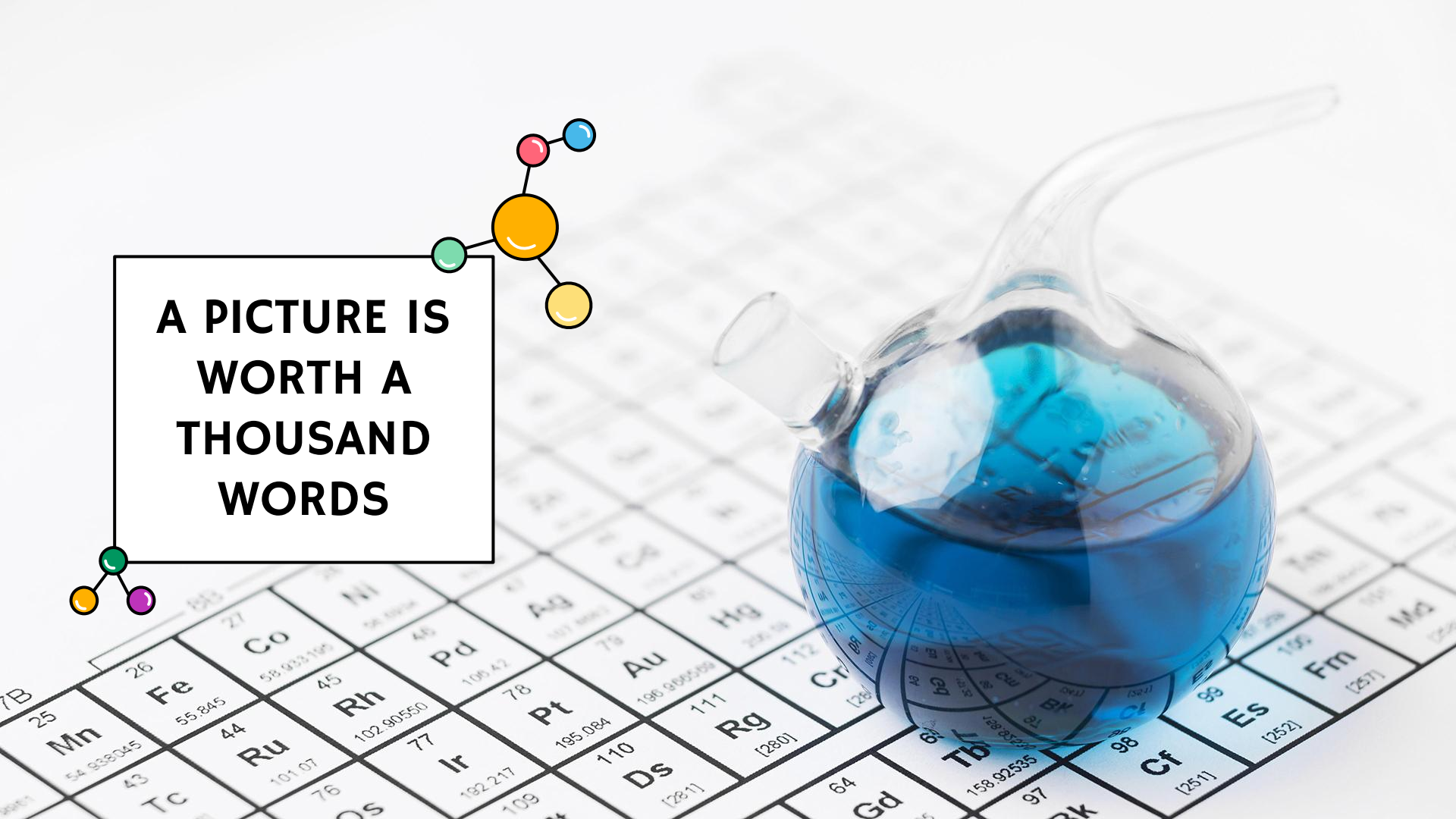
Venus has a beautiful name and is the second planet from the Sun. It's hot and has a poisonous atmosphere

TRANSITION METALS

		
SCANDIUM	**TITANIUM**	**VANADIUM**
Mercury is the closest planet to the Sun	Venus is the second planet from the Sun	Despite being red, Mars is actually a very cold place
		
YTTRIUM	**ZIRCONIUM**	**NIOBIUM**
Jupiter is the biggest planet of them all	Saturn is composed of hydrogen and helium	Neptune is the farthest planet from the Sun

AWESOME WORDS

A PICTURE IS WORTH A THOUSAND WORDS

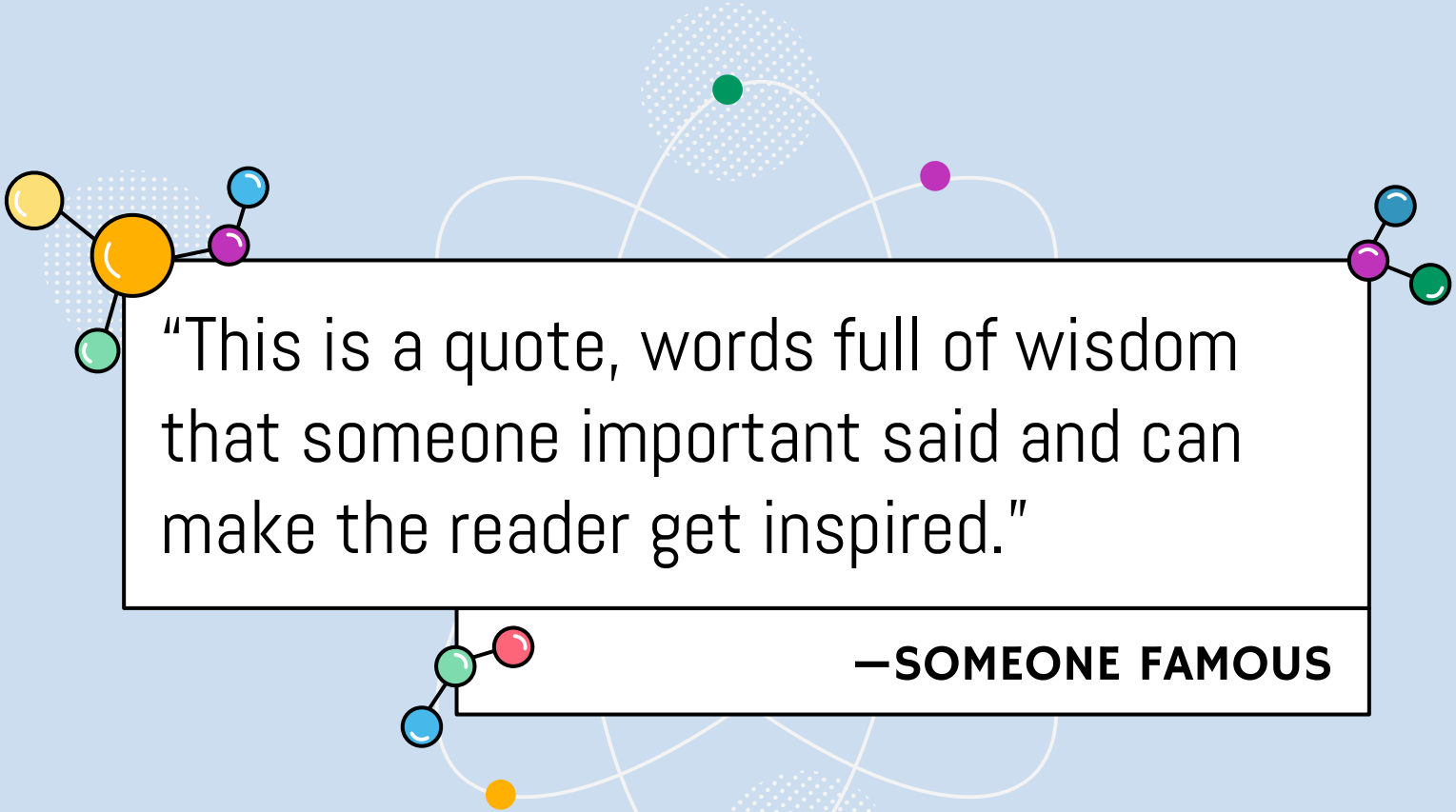


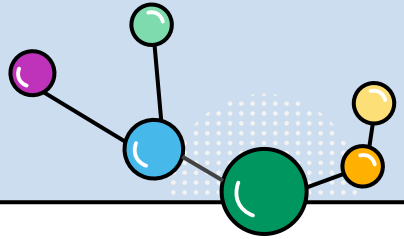
TEXT AND PHOTO

You can give a brief description of the topic you want to talk about here. For example, if you want to talk about Mercury, you can say that it's the smallest planet in the entire Solar System

TEXT AND PHOTO 3

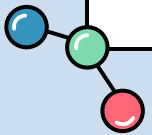
You can give a brief description of the topic you want to talk about here. For example, if you want to talk about Mercury, you can say that it's the smallest planet in the entire Solar System

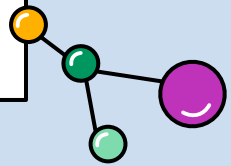

“This is a quote, words full of wisdom that someone important said and can make the reader get inspired."
—SOMEONE FAMOUS

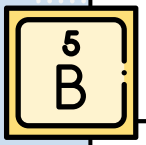


123,456,789

Big numbers catch your audience's attention



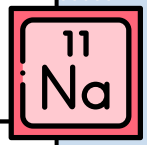




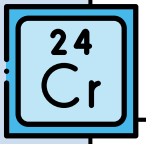
10.811 u

It's the atomic mass of Boron

22.990 u



It's the atomic mass of Sodium



51.996 u

It's the atomic mass of Chromium

19
K

23%

Venus is the second planet from the Sun

25
Mn

45%

Jupiter is the biggest planet in the Solar System

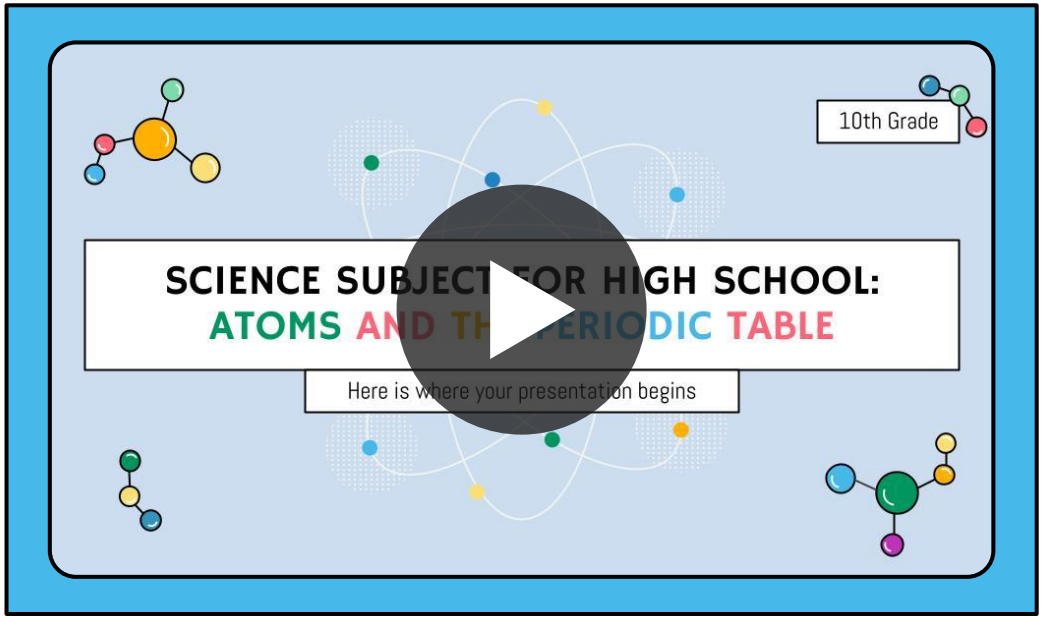
13
Al

78%

Despite being red, Mars is a cold place

VIDEO TUTORIAL

You can replace the image on the screen with your own work. Just right-click on it and select “Replace image”



TABLET SCREENSHOT

You can replace the image on the screen with your own work. Just right-click on it and select “Replace image”

PHONE SCREENSHOT

You can replace the image on the screen with your own work. Just right-click on it and select “Replace image”

THIS IS A GRAPH

88 Ra

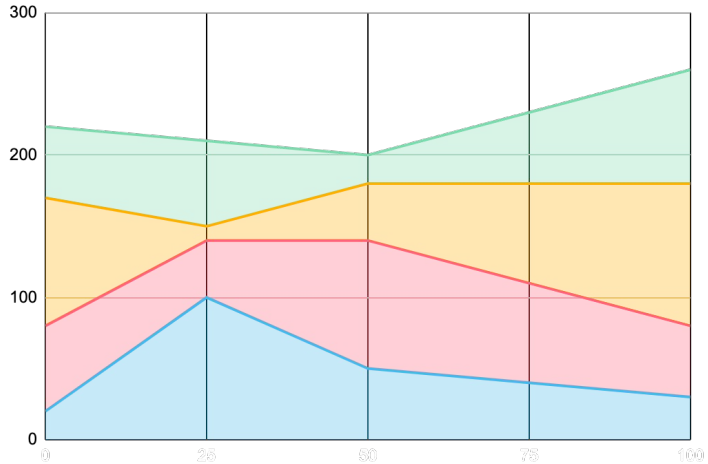
MERCURY

It's the closest planet to the Sun

72 Hf

MARS

Despite being red, Mars is cold



15 P

VENUS

It's the second planet from the Sun

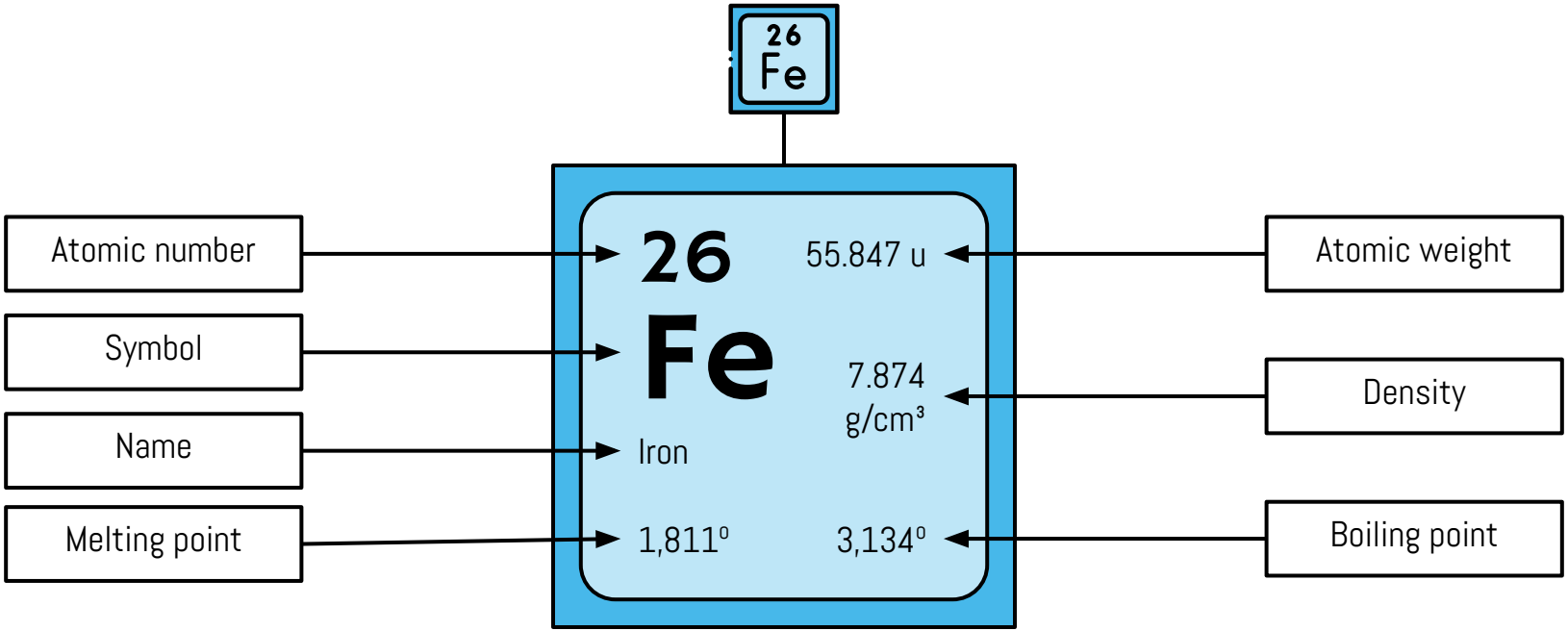
10 Ne

JUPITER

It's the biggest planet of them all

Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

ELEMENT INFORMATION



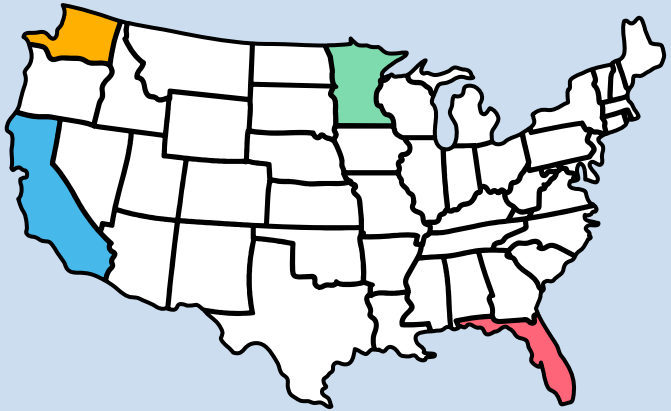
BEST CHEMISTRY SCHOOLS

MERCURY

It's the closest planet to the Sun

MARS

Despite being red, Mars is cold



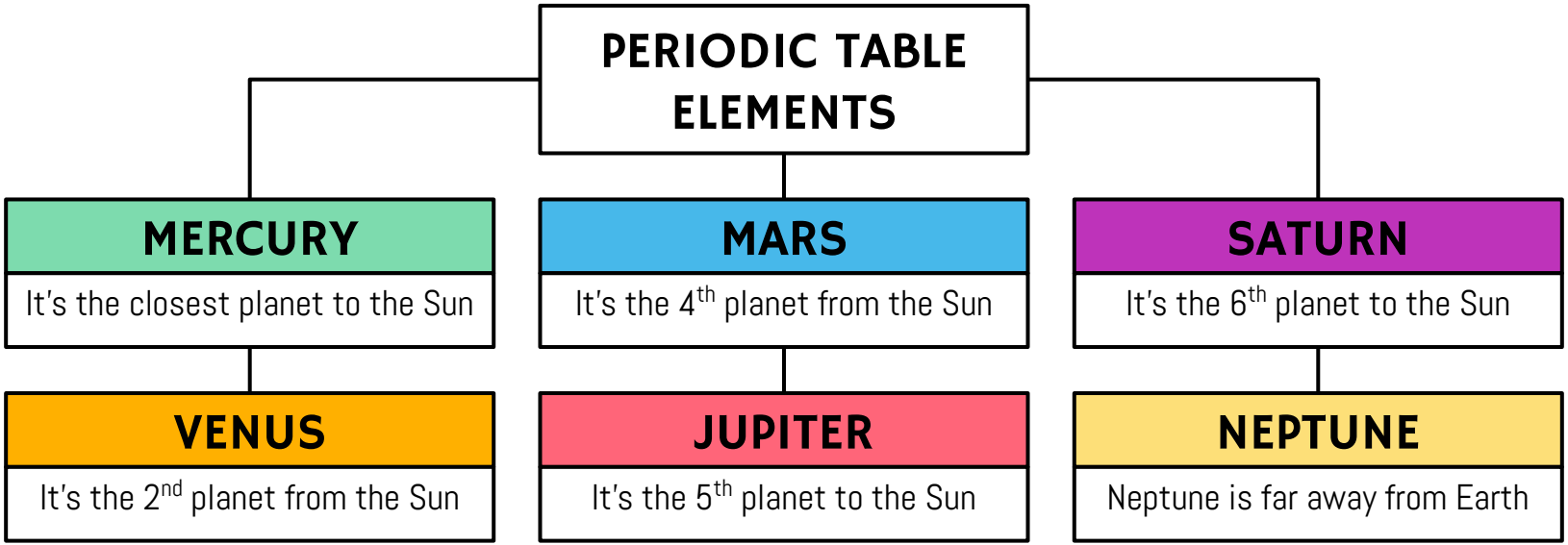
VENUS

It's the second planet from the Sun

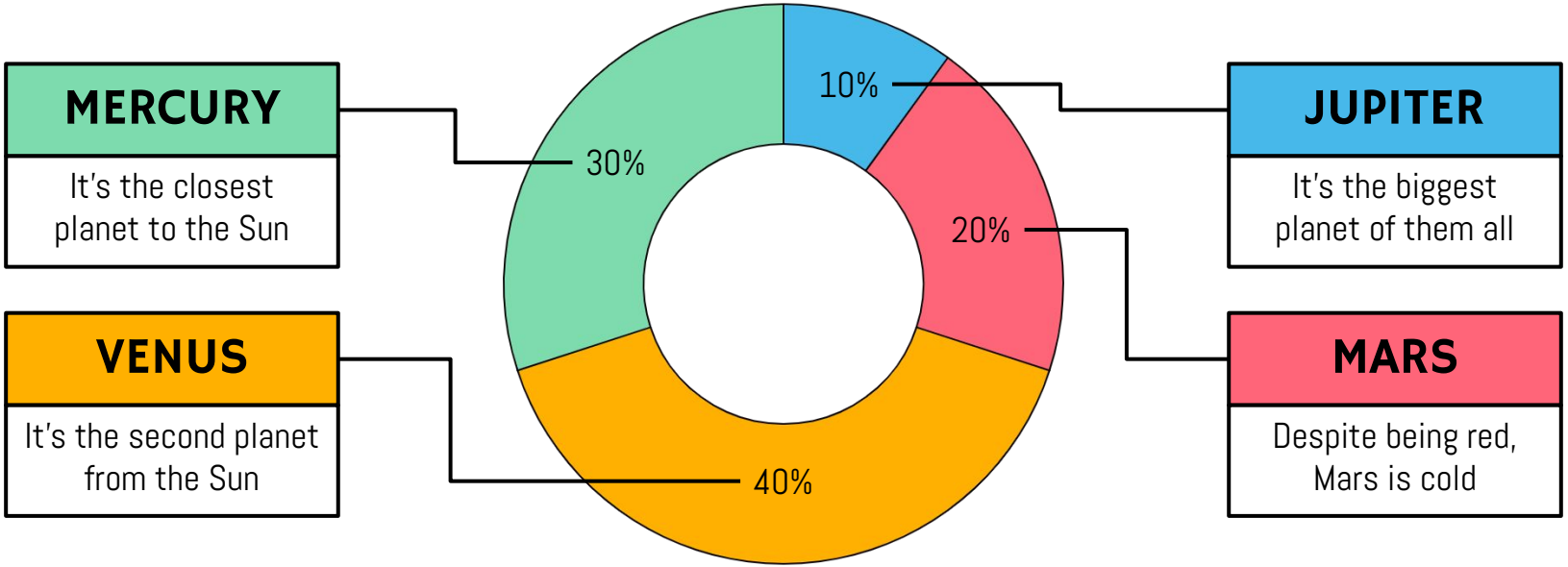
JUPITER

It's the biggest planet of them all

INFOGRAPHIC DIAGRAM

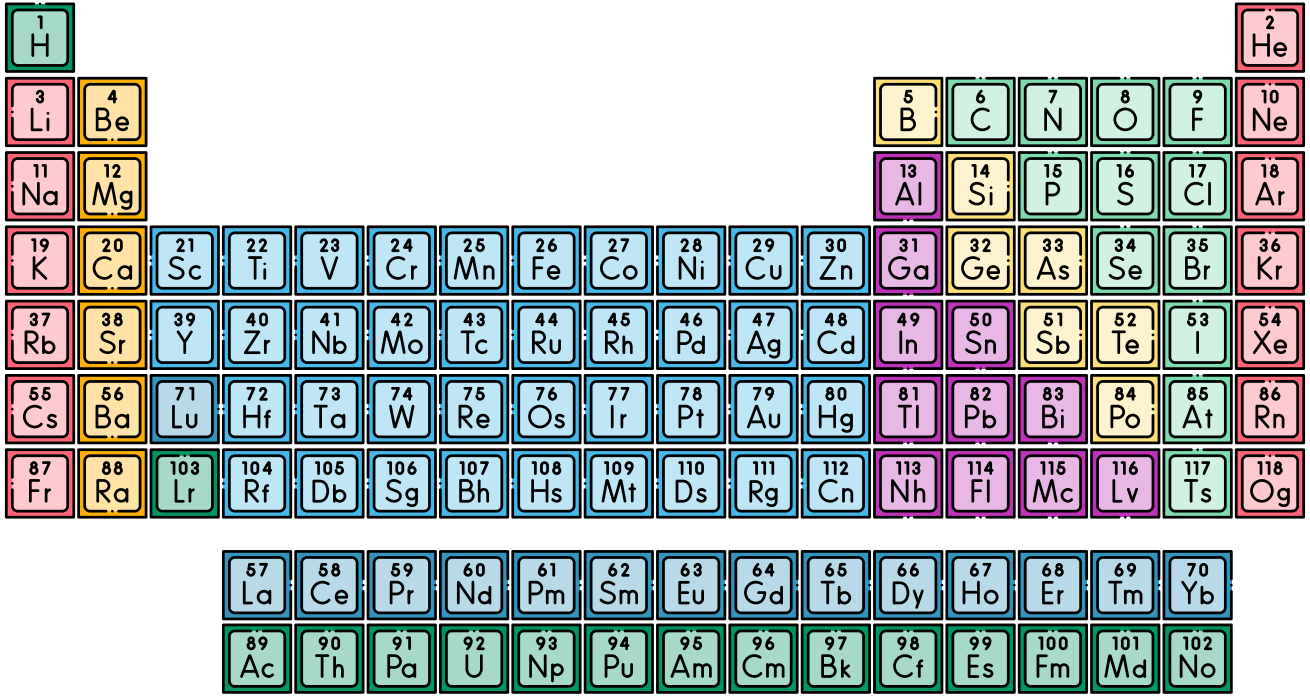


THIS IS ANOTHER GRAPH



Follow the link in the graph to modify its data and then paste the new one here. **For more info, click here**

ICON PACK: PERIODIC TABLE



ALTERNATIVE RESOURCES

Here's an assortment of alternative resources whose style fits the one of this template:

Photos

- Man in lab doing experiments
- Still life arrangement of test tubes
- Senior woman teaching english
- Teacher standing and holding tablet
- Close up scientist wearing face mask
- Children learning more about chemistry in class
- Scientist working with chemical substances
- Girls learning more about chemistry in class
- Chemistry class elements with copy space
- Still life assortment of test tubes

RESOURCES

Did you like the resources on this template? Get them for free at our other websites:

Photos

- Top view world science day arrangement
- Front view science elements with chemicals assortment
- Male researcher in the biotechnology laboratory with tablet
- Side view of female scientist holding lab substance
- Medium shot woman with chemical substance
- Pretty girl learning more about chemistry in class
- Top view science elements
- High angle science elements composition
- High angle science elements with chemicals composition
- High angle science elements with chemicals assortment

Icons

- Icon pack: Periodic table

Instructions for use

In order to use this template, you must credit **Slidesgo** by keeping the **Thanks** slide.

You are allowed to:

- Modify this template.
- Use it for both personal and commercial projects.

You are not allowed to:

- Sublicense, sell or rent any of Slidesgo Content (or a modified version of Slidesgo Content).
- Distribute Slidesgo Content unless it has been expressly authorized by Slidesgo.
- Include Slidesgo Content in an online or offline database or file.
- Offer Slidesgo templates (or modified versions of Slidesgo templates) for download.
- Acquire the copyright of Slidesgo Content.

For more information about editing slides, please read our FAQs or visit Slidesgo School:
https://slidesgo.com/faqs and https://slidesgo.com/slidesgo-school

Instructions for use (premium users)

As a Premium user, you can use this template without attributing **Slidesgo** or keeping the "Thanks" slide.

You are allowed to:

- Modify this template.
- Use it for both personal and commercial purposes.
- Hide or delete the “Thanks” slide and the mention to Slidesgo in the credits.
- Share this template in an editable format with people who are not part of your team.

You are not allowed to:

- Sublicense, sell or rent this Slidesgo Template (or a modified version of this Slidesgo Template).
- Distribute this Slidesgo Template (or a modified version of this Slidesgo Template) or include it in a database or in any other product or service that offers downloadable images, icons or presentations that may be subject to distribution or resale.
- Use any of the elements that are part of this Slidesgo Template in an isolated and separated way from this Template.
- Register any of the elements that are part of this template as a trademark or logo, or register it as a work in an intellectual property registry or similar.

For more information about editing slides, please read our FAQs or visit Slidesgo School:
https://slidesgo.com/faqs and https://slidesgo.com/slidesgo-school

Fonts & colors used

This presentation has been made using the following fonts:

Hammersmith One
(https://fonts.google.com/specimen/Hammersmith+One)

Abel
(https://fonts.google.com/specimen/Abel)

Storyset

Create your Story with our illustrated concepts. Choose the style you like the most, edit its colors, pick the background and layers you want to show and bring them to life with the animator panel! It will boost your presentation. Check out how it works.

Pana

Amico

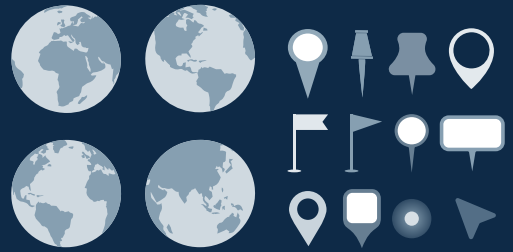
Bro

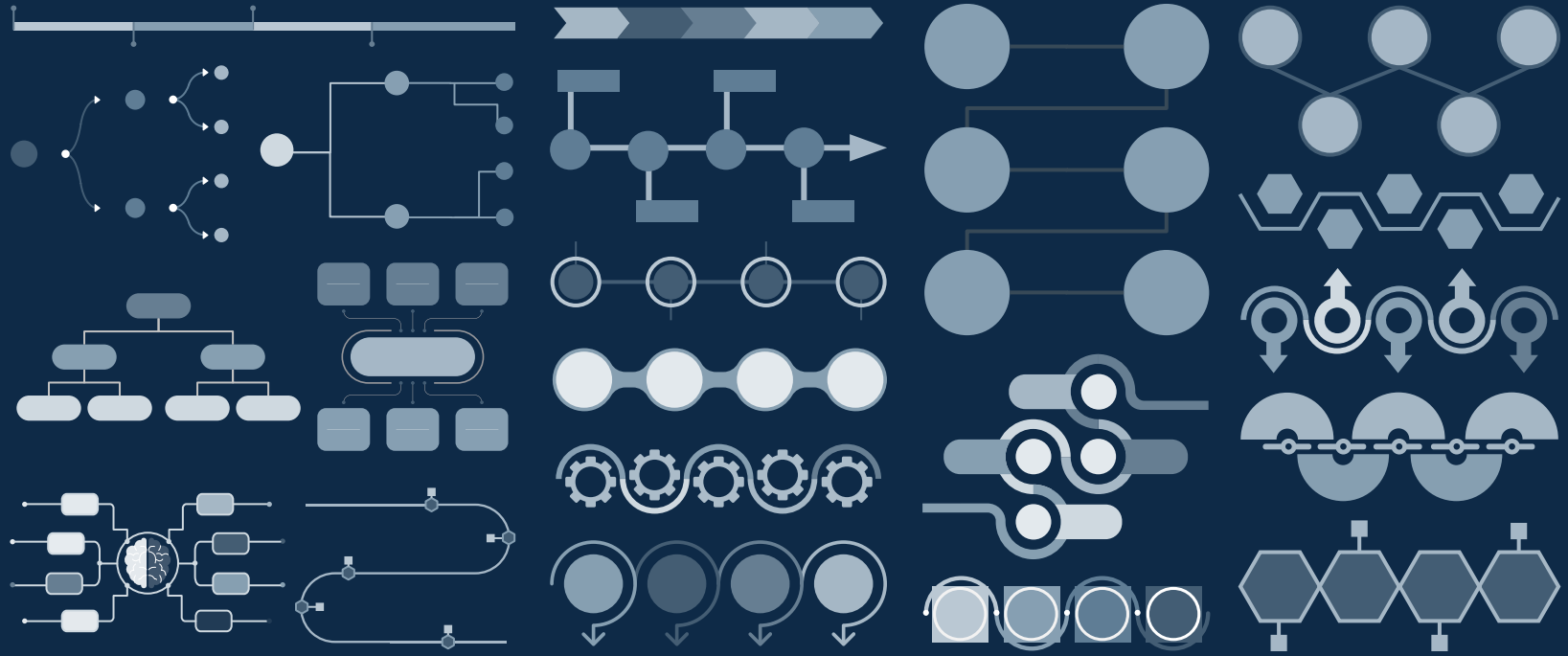
Rafiki

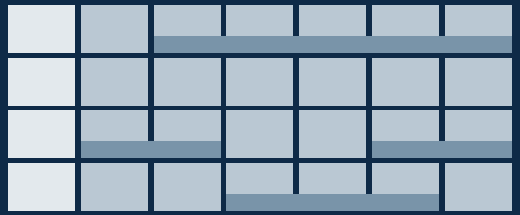
Cuate

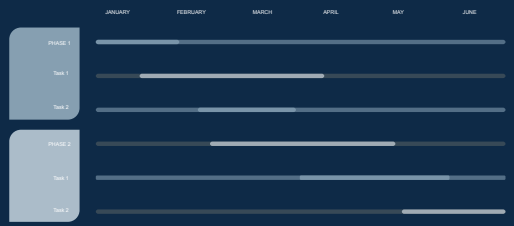
Use our editable graphic resources...

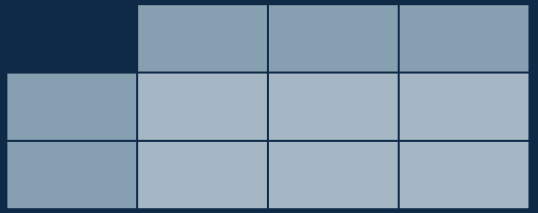
You can easily resize these resources without losing quality. To change the color, just ungroup the resource and click on the object you want to change. Then, click on the paint bucket and select the color you want. Group the resource again when you're done. You can also look for more infographics on Slidesgo.

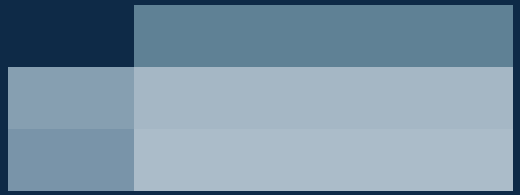


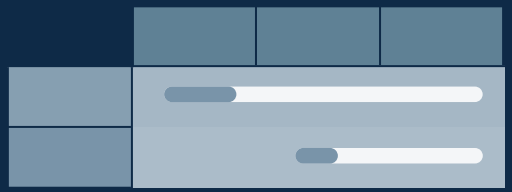


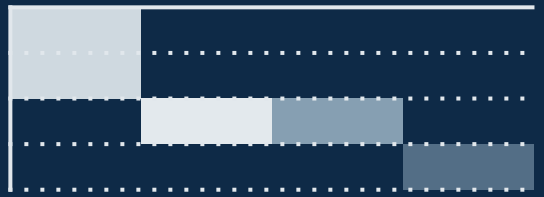


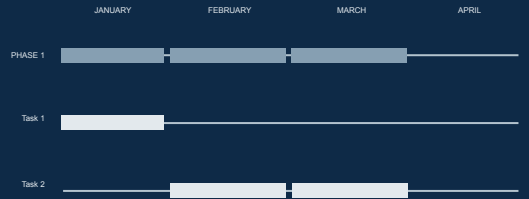

JANUARY
FEBRUARY
MARCH
APRIL
MAY
JUNE
PHASE 1
Task 1
Task 2
PHASE 2
Task 1
Task 2

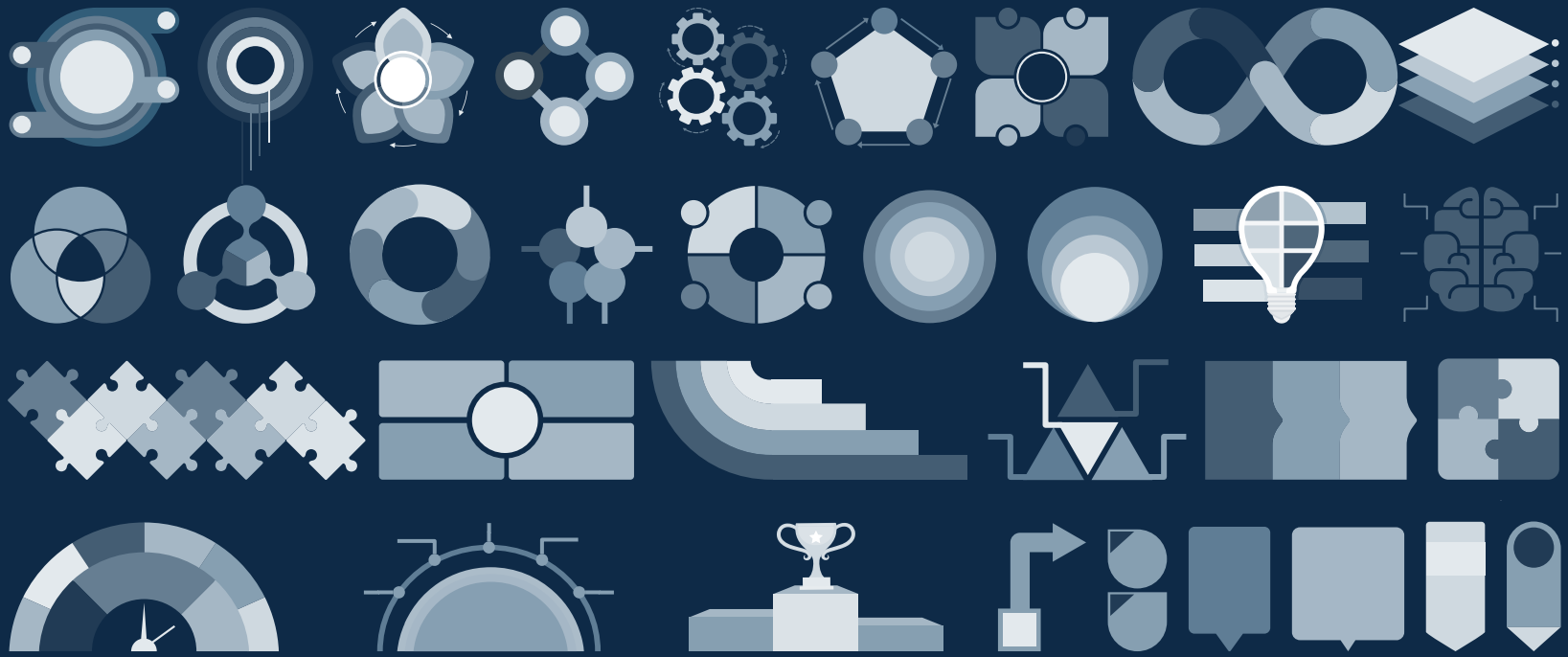









JANUARY
FEBRUARY
MARCH
APRIL
PHASE 1
Task 1
Task 2



...and our sets of editable icons

You can resize these icons without losing quality.
You can change the stroke and fill color; just select the icon and click on the paint bucket/pen.
In Google Slides, you can also use Flaticon's extension, allowing you to customize and add even more icons.

Educational Icons

Medical Icons

Business Icons

Teamwork Icons

Help & Support Icons

Avatar Icons

Creative Process Icons

Performing Arts Icons

Nature Icons

SEO & Marketing Icons


slidesgo