
# Syllabus

## 1. Overview

The StemCo syllabus is inspired by the Singapore education curriculum. Singapore is known for its excellence in PISA tests for Sciences for the last few years. Results from PISA indicate the quality and equity of learning outcomes attained around the world. By adopting the Singapore education curriculum as a reference, StemCo provides an opportunity for students globally to learn from one of the best practices of education in the world.

Our approach prioritizes understanding, application, and analysis of scientific and mathematical concepts over rote memorization of factual material. This shift in focus is intentional, recognizing the need for students to develop skills with long-term value in an increasingly technological world. Rather than concentrating on large volumes of factual information with limited short-term relevance, StemCo emphasizes critical thinking and practical application of learned concepts.

## 2. Categories and Exam Format

This document outlines the syllabus for each StemCo Chemistry category. The corresponding international grade levels and their Singapore grade-level equivalents are provided below for reference. All categories are assessed entirely through **Multiple-Choice Questions (MCQs)**.

| Category | International Grade Level | Singapore Grade Level Equivalent | Number of Questions (MCQ) | Exam Duration (Minutes) |
|---|---|---|---|---|
| Singa Junior | 9-10 | Secondary 3-4 | 40 | 120 |
| Singa Senior | 11-12 | Junior College 1-2 | 40 | 120 |

## 3. Syllabus

The StemCo syllabus is designed to cover essential areas and concepts crucial for a holistic understanding of subjects. While it provides a general framework for the topics featured in StemCo competitions, it is not intended to be exhaustive or overly detailed. Our goal is to provide an opportunity for students that encourages deep comprehension and real-world problem-solving, preparing them for future success in dynamic and unpredictable environments.

The syllabus includes a category called "Others" for concepts that don’t fit into the main topics. This section may include questions about recent advancements, trends, and discoveries related to the subject area, designed to be inspiring. Questions in this category can also be more advanced.

# Singa Junior

| Areas | Concepts |
|---|---|
| Experiment Techniques | Chromatography, Distillation, Filtration, Decanting, Separating Funnel, Heating, Crystallisation, Titration, Qualitative Analysis (Flame Tests: Grades 11-12) |
| Particulate Matter | Kinetic Particle Theory, Atomic Structure (Protons, Neutrons, Electrons; Isotopes, Atomic Notations etc.) |
| Bonding | Ionic & Covalent Bonding (including Structure & Properties of Materials), Van der Waals' Forces |
| Reactions | Neutralisation, Redox, Energetics (exclude Hess' Law), Simple Speed of Reaction (exclude Orders of Reaction), Electrochemistry (exclude use of Faraday Constant) |
| Moles & Stoichiometry | Relative Atomic Mass, Molar Mass, Concentration, Avogadro's Constant, %-yield & purity, r.t.p. & s.t.p., Volumes, Empirical & Molecular Formula |
| Air & Atmosphere | Earth's Atmospheric Composition, Acid Rain, CFCs, Greenhouse Gases, Carbon-Cycle, Carbon Monoxide & other Air Pollutants, Haber Process |
| Metals | Metallic Bonding, Alloys, Reactivity Series, Metal Displacement, Rusting, Stability of Metal Ores, Iron Extraction from Blast Furnace |
| Organic Chemistry | Homologous Series, Crude Oil, Alkanes, Alkenes, Alcohols, Carboxylic Acids, Esters, Addition & Condensation Polymerisation |
| Others | ... |

## Sample Questions

## QUESTION 1

### Fritz Haber: Hero or Mass Murderer?

Fritz Haber was awarded the Nobel Prize in Chemistry in 1918 for figuring out how to extract $N_2(g)$ from air and convert it to $NH_3(g)$. This process earned its nickname "bread from the air" as it helped save many lives from global food insecurity during that period (and still helps to provide global food security today).

However, his Nobel Prize was overshadowed and reputation heavily disputed due to his other dark side, the "Father of Chemical Warfare", developing explosives and $Cl_2(g)$ during WWI. Another of his research was unfortunately developed into Zyklon B, a gas used to mass exterminate Jews during the Holocaust of WWII.


Zyklon B contained the gas hydrogen cyanide, HCN(g). Which of the following statements regarding HCN(g) is false?

A. It is likely to dissolve in water to give a solution that turns blue Litmus Paper red.
B. HCN has a much lower boiling point as compared to $H_2O$.
C. HCN is able to readily react with Carboxylic Acids in a Neutralisation reaction.
D. There is the presence of covalent bonding in a molecule of HCN.

## QUESTION 2

### Relative Atomic Mass of StemCo

On planet X, a rare element known as StemCo has been discovered. Scientists are able to extract a rare sample of it from the planet's surface and run some tests, figuring that it has 3 main isotopes with relative atomic masses 135, 137 and 138, with a corresponding abundance ratio of 1:5:3.


What is the closest equivalent element on Earth for this newly discovered element on planet X?

A. Barium (Relative Atomic Mass = 137.3)
B. Lanthanum (Relative Atomic Mass = 138.9)
C. Caesium (Relative Atomic Mass = 132.9)
D. Xenon (Relative Atomic Mass = 131.3)v

## QUESTION 3

### Captain America's Vibranium Shield

In the World of Avengers, some scientists are trying to uncover the secrets of Captain America's Vibranium shield, as they wondered why the shield is generally rigid, unmalleable and indestructible (so far, only Thanos was able to destroy it during the movie Avengers Endgame).

Which of the following findings is unlikely to be uncovered by the scientists about Captain America's Vibranium shield?

A. The shield cannot be easily deformed/damaged.
B. Electrons can move freely in the shield.
C. The shield is a good conductor of heat.
D. The shield melts at a fixed temperature.

## QUESTION 4

### Chemical Weighing

Adam is a chemistry enthusiast. He had a sample of copper(II) nitrate and wanted to determine its mass. However, he didn't have an absolute scale in his lab — only a comparative one.
To solve this, he measured out an equal mass of copper(II) chloride and combined it with the copper(II) nitrate sample. He then dissolved the mixture in 50 grams of water.
After conducting an analysis, he determined that the mass fraction of copper in the resulting solution was 5%.
What was the mass of the original copper(II) nitrate sample?
A) 3.52 g
B) 3.08 g
C) 2.50 g
D) 1.25 g

## QUESTION 5

### Cool Flam

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People often claim that compound A produces an unusually cool flame — so cool that it doesn't char paper and doesn't burn your skin. Intrigued by this claim, Alice decided to investigate the compound's composition. She found that compound A can be synthesized by reacting compound B and compound C, both of which are simple substances:

Compound B is a porous black solid formed during the pyrolysis of wood without air.

Compound C is a yellow crystalline substance found in nature in its native elemental form as an 8-membered ring

What is the molar mass of compound A?

A. 76 g/mol
B. 44 g/mol
C. 32 g/mol
D. 68 g/mol

# Singa Senior

| Areas | Concepts |
|---|---|
| Moles & Stoichiometry | Relative Atomic Mass, Molar Mass, Concentration, Avogadro's Constant, %-yield & purity, r.t.p. & s.t.p., Volumes, Empirical & Molecular Formula, ppm & ppb |
| Atomic Structure | Bohr's vs. Quantum Mechanical Model, s, p, d & f Orbitals; Hund's Rule, Aufbau Principle, Pauli Exclusion Principle, Atomic & Ionic Radii/Size Comparisons |
| Bonding | Ionic, Covalent & Dative Bonding; Intermediate-Type Bonding, Bond Length & Polarity, Molecular Geometry & VSEPR Theory, Intermolecular Forces |
| Reactions | Neutralisation, Redox, Energetics & Entropy, Reaction Kinetics (inclusive of Orders of Reaction, Half-Life, Mechanistic Steps etc.), Equilibrium, Electrochemistry |
| Gaseous State | Ideal Gas Equation, Boyle's Law, Charles' Law, Graham's Law, Dalton's Law of Partial Pressures, Real Gas |
| Periodicity | Trends across Periods (Electronegativity, Ionisation Energy, Electron Affinity, Oxides & Chlorides) & down/up Groups, Group 2 & Group 17 Properties |
| Transition Metals | Structure & Properties (due to partially-filled d-orbitals e.g., Colour, Variable Oxidation States, Complexation with Ligands & Crystal Field Theory etc.) |
| Organic Chemistry | Alkanes, Alkenes, Alkyl Halides, Aromatic Compounds, Hydroxyl & Carbonyl Compounds, Carboxylic Acid & Derivatives, Amines, Proteins, Peptides & Amino Acids |
| Others | ... |

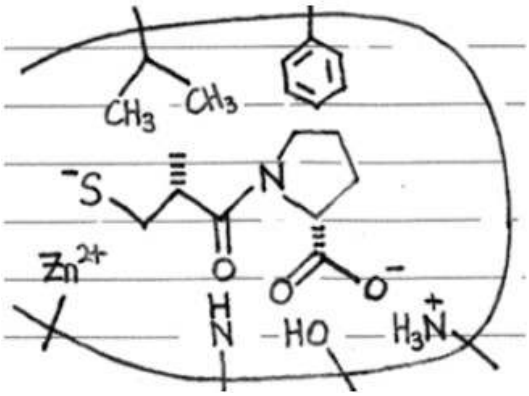
## Sample Questions

## QUESTION 1

### Captopril - An Antihypertensive Medication

Hypertension is a chronic disease that not just affects many elderly Singaporeans, but also many people worldwide. In the 1960s, the venom of a Brazilian viper led to the development of 1 such medication to combat hypertension still used today, Captopril.

Below is an image of Captopril "docking" itself into the active site of ACE (angiotensin-converting enzyme). This will trigger downstream effects that eventually lead to lowering of blood pressure for the patient:



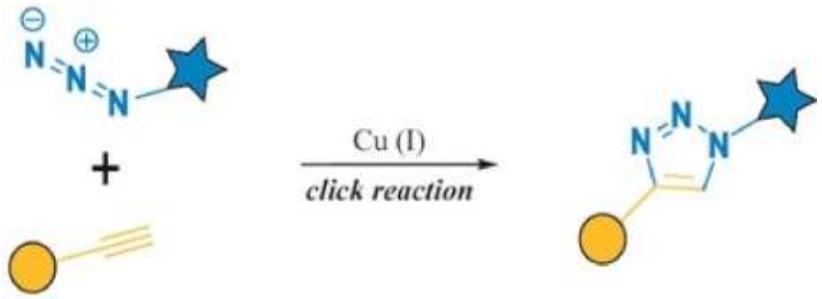

Which of the following intermolecular forces is not present in assisting Captopril in "docking" itself into the active site of ACE?

A. Hydrogen Bonding
B. London Dispersion Forces
C. Ionic Electrostatic Attraction
D. Ion-Dipole Interaction

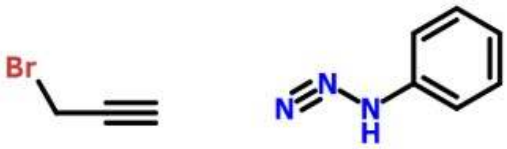
## QUESTION 2

### Copper & 2022 Nobel Prize in Chemistry

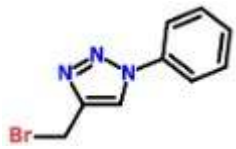
The phrase" click chemistry" became popular with the announcement of the 2022 Nobel Prize in Chemistry. Just as the name goes, it can make organic synthesis as easy as building LEGO. It has the potential to open up a new era for organic synthesis because desirable and specific products can possibly be formed easily in common and non-toxic media like water without any stringent conditions required.



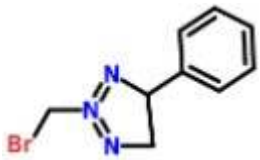

The above is an example of a "click chemistry" reaction discovered by Dr. Morten Meldal, one of the laureates of the 2022 Nobel Prize in Chemistry.




What is the product if you "click" the following two molecules above together?

A. 

B. 

C. 

D. 

## QUESTION 3

### Chemistry Lab Chaos

Gabriel is a student enrolled in Mr. Khoo's Chemistry class. In this particular class, a laboratory session, Mr. Khoo instructed students to pour out 20ml of a 0.008mol/l solution HCl(aq) into a beaker for measurement of pH, via a pH logger.


However, Gabriel, being very playful, decided to add in 15ml of 0.008mol/l solution of HCl(aq) into the beaker and 5ml of 0.01mol/l $H_2SO_4$(aq) into the beaker.

How much is the difference of Gabriel's pH value compared to his classmates?

A. 0.14
B. 2.09
C. 1.95
D. 2.03

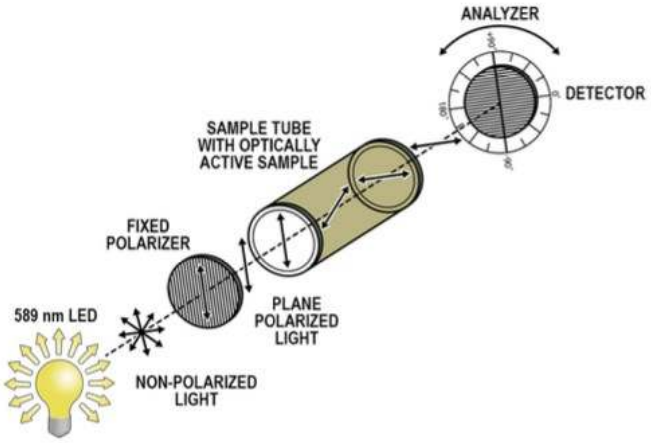
**QUESTION 4**

**Polarimetry**

Polarimetry is an analytical technique used to measure the optical rotation of chiral substances (those that rotate plane-polarized light). It's commonly used in chemistry to determine the concentration or purity of optically active compounds, like sugars or enantiomers.

How does it work?

Plane-polarized light is passed through a sample. If the substance is optically active, it rotates the light either to the right (dextrorotatory, +) or left (levorotatory, –). The instrument (a polarimeter) measures the angle of rotation, α (alpha).




Each compound has its own specific rotation, described by the formula:

$$[\alpha] = \frac{\alpha_{obs}}{l \cdot c}$$

, where [α] - specific rotation, αobs - observed rotation (in degrees) measured by the polarimeter, l - path length of the sample tube, c - concentration of the solution.

A sample of sucrose, $C_{12}H_{22}O_{11}$ was analyzed using polarimetry. It was placed in a 20 cm-long tube, and

the observed optical rotation was +6.60°. Given that the specific rotation of sucrose is +66.53°·cm$^3$·g$^{-1}$·dm$^{-1}$, what is the concentration of sucrose, $C_{12}H_{22}O_{11}$ in the sample?

A. 0.145 mol/dm$^3$
B. 0.0496 mol/dm$^3$
C. 0.066 mol/dm$^3$
D. 0.276 mol/dm$^3$

## QUESTION 5

Unknown Refrigerant

The saturated hydrocarbon A is used as a component of fuel for internal combustion engines, in gas lighters and refill cartridges, as well as a propellant in aerosol sprays. Additionally, this hydrocarbon is used as a refrigerant in household refrigerators, as it does not deplete the ozone layer and allows for reduced energy consumption.

It is known that the relative density of hydrocarbon A compared to air does not exceed 3. Upon chlorination, A produces a mixture of only two monochlorinated derivatives, B1 and B2. When this mixture is treated with an alcoholic solution of potassium hydroxide, it yields only one compound C. Upon acid-catalyzed hydration of compound C, a single product D is formed, in which the mass fraction of oxygen is 21.6%.

What is the IUPAC name of hydrocarbon A?

A. Methylpropane
B. Propane
C. N-butane
D. 2,2-dimethylpropane