IB CHEMISTRY HL YEAR 1 - Unit 4

IB Chemistry HL PLC		**Subject Group and Course**	Group 4 - HL Chemistry		
Course Part and Topic	**UNIT 4 - Energetics and Kinetics** Reactivity 1.1 - Measuring enthalpy changes Reactivity 1.2 - Energy cycles in reactions Reactivity 1.3 - Energy from fuels Reactivity 1.4 - Entropy and spontaneity Reactivity 2.2 - How Fast? The Rate of Chemical Change Reactivity 2.3 - How Far? The Extent of Chemical Change	**SL or HL / Year 1 or 2**	HL Year 1	**Dates**	Semester 2 - Weeks 9 to 18
Unit Description and Texts		**DP Assessment(s) for Unit**			
● Chemistry for the IB Diploma Third Edition, Hodder Education		● Unit 04 Summative Assessment - *Paper 1 and 2 questions modeled after the real IB Exam Papers (2025 syllabus)*			

INQUIRY: establishing the purpose of the unit

Transfer Goals

List here one to three big, overarching, long-term goals for this unit. Transfer goals are the major goals that ask students to "transfer" or apply their knowledge, skills, and concepts at the end of the unit under new/different circumstances, and on their own without scaffolding from the teacher.

Phenomenon: Utilizing bioethanol in internal combustion engines showcases the renewable and carbon-neutral nature of biofuels, providing a cleaner and more sustainable alternative to fossil fuels.

Statement of Inquiry: The underlying factors influencing reaction pathways allow for the development of novel strategies for energy conversion and chemical synthesis across scientific disciplines and technological applications.

1. **Students can** explain the challenges of using chemical energy to address our energy needs.
2. **Students can** use temperature change to deduce information about chemical and physical changes.
3. **Students can** apply the law of conservation of energy to predict energy changes during reactions.
4. **Students can** explain how the rate of a reaction can be controlled.
5. **Students can** explain how the extent of a reversible reaction can be influenced.

ACTION: teaching and learning through inquiry

Content / Skills / Concepts - Essential Understandings	**Learning Process** *Check the boxes for any pedagogical approaches used during the unit. Aim for a variety of approaches to help facilitate learning.*
Reactivity 1.1.1 **Chemical reactions involve a transfer of energy between the system and the surroundings, while total energy is conserved.** *Understand the difference between heat and temperature.* **Reactivity 1.1.2** **Reactions are described as endothermic or exothermic, depending on the direction of energy transfer between the system and the surroundings.** *Understand the temperature change (decrease or increase) that accompanies endothermic and exothermic reactions, respectively.* **Reactivity 1.1.3** **The relative stability of reactants and products determines whether reactions are endothermic or exothermic.** *Sketch and interpret energy profiles for endothermic and exothermic reactions.* ● Axes for energy profiles should be labelled as reaction coordinate x , potential energy y **Reactivity 1.1.4** **The standard enthalpy change for a chemical reaction, $\Delta H^{\ominus}$, refers to the heat transferred at constant pressure under standard conditions and states. It can be determined from the change in temperature of a pure substance.** *Apply the equations $Q = mc\Delta T$ and $\Delta H = -Q/n$ in the calculation of the enthalpy change of a reaction.* ● The units of $\Delta H^{\ominus}$ are kJ mol^{-1}. ● The equation $Q = mc\Delta T$ and the value of c, the specific heat capacity of water, are given in the data booklet. **Reactivity 1.2.1** **Bond-breaking absorbs and bond-forming releases energy.** *Calculate the enthalpy change of a reaction from given average bond enthalpy data.* ● Include explanation of why bond enthalpy data are average values and may differ from those measured experimentally. ● Average bond enthalpy values are given in the data booklet. **Reactivity 1.2.2** **Hess's law states that the enthalpy change for a reaction is independent of the pathway between the initial and final states.** *Apply Hess's law to calculate enthalpy changes in multistep reactions.* **Reactivity 1.2.3** **Standard enthalpy changes of combustion, $\Delta Hc \ominus$, and formation, $\Delta Hf \ominus$, data are used in thermodynamic calculations.** *Deduce equations and solutions to problems involving these terms.* **Reactivity 1.2.4** **An application of Hess's law uses enthalpy of formation data or enthalpy of combustion data to calculate the enthalpy change of a reaction.**	Learning experiences and strategies/planning for self-supporting learning: ☒ Lecture ☐ Socratic seminar ☒ Small group/pair work ☒ PowerPoint lecture/notes ☒ Individual presentations ☒ Group presentations ☒ Student lecture/leading ☐ Interdisciplinary learning Details: *Students will learn through a combination of presentations, small group work, practice problems, and lab work.* ☒ Other(s): *practice problems, lab work*
	Formative assessment(s): *Topic quizzes throughout unit* *Practice with Tools and Inquiries* *Daily formative checks*
	Summative assessments:

Calculate enthalpy changes of a reaction using $\Delta H_f^{\ominus}$ data or $\Delta H_c^{\ominus}$ data.
$\Delta H^{\ominus}=\Sigma\Delta H_f^{\ominus}\text{products} - \Sigma\Delta H_f^{\ominus}\text{reactants}$
$\Delta H^{\ominus}=\Sigma\Delta H_c^{\ominus}\text{reactants} - \Sigma\Delta H_c^{\ominus}\text{products}$

Reactivity 1.2.5
A Born–Haber cycle is an application of Hess's law, used to show energy changes in the formation of an ionic compound.
Interpret and determine values from a Born–Haber cycle for compounds composed of univalent and divalent ions.

Reactivity 1.3.1
Reactive metals, non-metals and organic compounds undergo combustion reactions when heated in oxygen.
Deduce equations for reactions of combustion, including hydrocarbons and alcohols.

Reactivity 1.3.2
Incomplete combustion of organic compounds, especially hydrocarbons, leads to the production of carbon monoxide and carbon.
Deduce equations for the incomplete combustion of hydrocarbons and alcohols.

Reactivity 1.3.3
Fossil fuels include coal, crude oil and natural gas, which have different advantages and disadvantages.
Evaluate the amount of carbon dioxide added to the atmosphere when different fuels burn.
Understand the link between carbon dioxide levels and the greenhouse effect.
- The tendency for incomplete combustion and energy released per unit mass should be covered.

Reactivity 1.3.4
Biofuels are produced from the biological fixation of carbon over a short period of time through photosynthesis.
Understand the difference between renewable and non-renewable energy sources.
Consider the advantages and disadvantages of biofuels.
- The reactants and products of photosynthesis should be known.

Reactivity 1.3.5
A fuel cell can be used to convert chemical energy from a fuel directly to electrical energy.
Deduce half-equations for the electrode reactions in a fuel cell.
- Hydrogen and methanol should be covered as fuels for fuel cells.
- The use of proton exchange membranes will not be assessed.

Reactivity 1.4.1
Entropy, S, is a measure of the dispersal or distribution of matter and/or energy in a system. The more ways the energy can be distributed, the higher the entropy. Under the same conditions, the entropy of a gas is greater than that of a liquid, which in turn is greater than that of a solid.
Predict whether a physical or chemical change will result in an increase or decrease in entropy of a system.
Calculate standard entropy changes, $\Delta S^{\ominus}$, from standard entropy values, $S^{\ominus}$.

Reactivity 1.4.2
Change in Gibbs energy, ΔG, relates the energy that can be obtained from a chemical reaction to the change in enthalpy, ΔH, change in entropy, ΔS, and absolute temperature, T.
Apply the equation $\Delta G^{\ominus}=\Delta H^{\ominus}-T\Delta S^{\ominus}$ to calculate unknown values of these terms.

Reactivity 1.4.3
At constant pressure, a change is spontaneous if the change in Gibbs energy, ΔG, is negative.

Unit Exam - *Paper 1 and 2 questions modeled after the real IB Exam Papers (2025 syllabus)*

Laboratory Assignment - *assessing Tools and Inquiries practiced in the Unit*

Differentiation:

☒ Affirm identity - build self-esteem

☒ Value prior knowledge

☒ Scaffold learning

☒ Extend learning

Details:

- *SWD/504 – Accommodations Provided*
- *ELL – Reading & Vocabulary Support*
- *Intervention Support*
- *Extensions – Enrichment Tasks and Project*

Tools and Inquiries:

Reactivity 1.1.2
- Tool 1, Inquiry 2—What observations would you expect to make during an endothermic and an exothermic reaction?

Reactivity 1.1.4
- Tool 1, Inquiry 1, 2, 3—How can the enthalpy change for combustion reactions, such as for alcohols or food, be investigated experimentally?
- Tool 1, Inquiry 3—Why do calorimetry experiments typically measure a smaller change in temperature than is expected from theoretical values?

Reactivity 1.3.2

Interpret the sign of ΔG calculated from thermodynamic data.
Determine the temperature at which a reaction becomes spontaneous.

Reactivity 1.4.4

As a reaction approaches equilibrium, ΔG becomes less negative and finally reaches zero.

Perform calculations using the equation $\Delta G=\Delta G^{\ominus}+RT \ln Q$ and its application to a system at equilibrium $\Delta G^{\ominus}=-RT \ln K$.

Reactivity 2.2.1

The rate of reaction is expressed as the change in concentration of a particular reactant/product per unit time.

Determine rates of reaction.

- Calculation of reaction rates from tangents of graphs of concentration, volume or mass against time should be covered.

Reactivity 2.2.2

Species react as a result of collisions of sufficient energy and proper orientation.

Explain the relationship between the kinetic energy of the particles and the temperature in kelvin, and the role of collision geometry.

Reactivity 2.2.3

Factors that influence the rate of a reaction include pressure, concentration, surface area, temperature and the presence of a catalyst.

Predict and explain the effects of changing conditions on the rate of a reaction.

Reactivity 2.2.4

Activation energy, Ea, is the minimum energy that colliding particles need for a successful collision leading to a reaction.

Construct Maxwell–Boltzmann energy distribution curves to explain the effect of temperature on the probability of successful collisions.

Reactivity 2.2.5

Catalysts increase the rate of reaction by providing an alternative reaction pathway with lower Ea.

Sketch and explain energy profiles with and without catalysts for endothermic and exothermic reactions.
Construct Maxwell–Boltzmann energy distribution curves to explain the effect of different values for Ea on the probability of successful collisions.

- Biological catalysts are called enzymes.
- The different mechanisms of homogeneous and heterogeneous catalysts will not be assessed.

Reactivity 2.2.6

Many reactions occur in a series of elementary steps. The slowest step determines the rate of the reaction.

Evaluate proposed reaction mechanisms and recognize reaction intermediates.
Distinguish between intermediates and transition states, and recognize both in energy profiles of reactions.

Reactivity 2.2.7

Energy profiles can be used to show the activation energy and transition state of the rate-determining step in a multistep reaction.

Construct and interpret energy profiles from kinetic data.

Reactivity 2.2.8

The molecularity of an elementary step is the number of reacting particles taking part in that step.

Interpret the terms “unimolecular”, “bimolecular” and “termolecular”.

- Inquiry 2—What might be observed when a fuel such as methane is burned in a limited supply of oxygen?

Reactivity 2.2.1

- Tool 1, 3, Inquiry 2—Concentration changes in reactions are not usually measured directly. What methods are used to provide data to determine the rate of reactions?
- Tool 1—What experiments measuring reaction rates might use time as i) a dependent variable ii) an independent variable?

Reactivity 2.2.3

- Tool 1—What variables must be controlled in studying the effect of a factor on the rate of a reaction?
- Nature of science, Tool 3, Inquiry 3—How can graphs provide evidence of systematic and random error?

Reactivity 2.2.10

- Tool 1, 3, Inquiry 2—What measurements are needed to deduce the order of reaction for a specific reactant?

Reactivity 2.2.9

Rate equations depend on the mechanism of the reaction and can only be determined experimentally.

Deduce the rate equation for a reaction from experimental data.

Reactivity 2.2.10

The order of a reaction with respect to a reactant is the exponent to which the concentration of the reactant is raised in the rate equation.

The order with respect to a reactant can describe the number of particles taking part in the rate-determining step.

The overall reaction order is the sum of the orders with respect to each reactant.

Sketch, identify and analyse graphical representations of zero, first and second order reactions.

Reactivity 2.2.11

The rate constant, k, is temperature dependent and its units are determined from the overall order of the reaction.

Solve problems involving the rate equation, including the units of k.

Reactivity 2.2.12

The Arrhenius equation uses the temperature dependence of the rate constant to determine the activation energy.

Describe the qualitative relationship between temperature and the rate constant.

Analyse graphical representations of the Arrhenius equation, including its linear form.

Reactivity 2.2.13

The Arrhenius factor, A, takes into account the frequency of collisions with proper orientations.

Determine the activation energy and the Arrhenius factor from experimental data.

Reactivity 2.3.1

A state of dynamic equilibrium is reached in a closed system when the rates of forward and backward reactions are equal.

Describe the characteristics of a physical and chemical system at equilibrium.

Reactivity 2.3.2

The equilibrium law describes how the equilibrium constant, K, can be determined from the stoichiometry of a reaction.

Deduce the equilibrium constant expression from an equation for a homogeneous reaction.

Reactivity 2.3.3

The magnitude of the equilibrium constant indicates the extent of a reaction at equilibrium and is temperature dependent.

Determine the relationships between K values for reactions that are the reverse of each other at the same temperature.

- Include the extent of reaction for: $K \ll 1$, $K < 1$, $K = 1$, $K > 1$, $K \gg 1$.

Reactivity 2.3.4

Le Châtelier's principle enables the prediction of the qualitative effects of changes in concentration, temperature and pressure to a system at equilibrium.

Apply Le Châtelier's principle to predict and explain responses to changes of systems at equilibrium.

- Include the effects on the value of K and on the equilibrium composition.
- Le Châtelier's principle can be applied to heterogeneous equilibria such as: $X(g) \rightleftharpoons X(aq)$

Reactivity 2.3.5

The reaction quotient, Q, is calculated using the equilibrium expression with nonequilibrium

concentrations of reactants and products. *Calculate the reaction quotient Q from the concentrations of reactants and products at a particular time, and determine the direction in which the reaction will proceed to reach equilibrium.* **Reactivity 2.3.6** **The equilibrium law is the basis for quantifying the composition of an equilibrium mixture.** *Solve problems involving values of K and initial and equilibrium concentrations of the components of an equilibrium mixture.* **Reactivity 2.3.7** **The equilibrium constant and Gibbs energy change, ΔG, can both be used to measure the position of an equilibrium reaction.**	

Approaches to Learning (ATL)

Check the boxes for any explicit approaches to learning connections made during the unit. For more information on ATL, please see the guide.

☒ Thinking

☒ Social

☒ Communication

☒ Self-management

☒ Research

Details:

Students will be continuously challenged to develop higher-order thinking skills as they take prior knowledge, combine it with new content, and synthesize new understandings and connections.

Students will build social groups through group work and intentional reflection activities.

Students will communicate their findings to their peers in the form of small-group presentations.

Students will continue to work on self-management and organization skills.

Students will complete background research to develop and extend their learning.

Language and Learning *Check the boxes for any explicit language and learning connections made during the unit. For more information on the IB's approach to language and learning, please see the guide.*	**TOK Connections** *Check the boxes for any explicit TOK connections made during the unit*	**CAS Connections** *Check the boxes for any explicit CAS connections. If you check any of the boxes, provide a brief note in the "details" section explaining how students engaged in CAS for this unit.*
☒ Activating background knowledge ☒ Scaffolding for new learning ☒ Acquisition of new learning through practice ☒ Demonstrating proficiency Details: *Content and vocabulary introduced in previous science courses will be used in this unit.* *Students will use many of the concepts from this unit in future units throughout the two-year course.* *Students will acquire new vocabulary.* *Students will continually demonstrate proficiency with chemistry vocabulary in class discussions and group work.*	☐ Personal and shared knowledge ☒ Ways of knowing ☐ Areas of knowledge ☐ The knowledge framework Details: *TOK knowledge questions will be included as discussion options for each lesson.*	☒ Creativity ☐ Activity ☐ Service Details: *Students will be encouraged to consider the creativity involved in scientific experimentation. Students can explore alternative ways (visual, for example) to express and explain this creativity to others.*

Resources

List and attach (if applicable) any resources used in this unit

Resources for 2025 Syllabus:

- Chemistry for the IB Diploma Third Edition, Hodder Education

- IB Chemistry Guide First Assessment 2025
- InThinking IB subject site for Chemistry
- IB Chemistry Schoology Course

REFLECTION: considering the planning, process, and impact of the inquiry

What worked well *List the portions of the unit (content, assessment, planning) that were successful*	**What didn't work well** *List the portions of the unit (content, assessment, planning) that were not as successful as hoped*	**Notes / Changes / Suggestions** *List any notes, suggestions, or considerations for the future teaching of this unit*