NANYANG TECHNOLOGICAL UNIVERSITY SINGAPORE

COURSE CONTENT

Academic Year	2024/2025	**Semester**	1
Course Coordinator	Asst Prof. Park Seung-min		
Course Code	BG2142		
Course Title	Biological Thermodynamics (Core)		
Pre-requisites	BG1103/CB2102/CB1103		
No of AUs	3		
Contact Hours	*26 hours lecture, 12 hours tutorial*		
Proposal Date	*27 May 2020*		

Course Aims

This course aims to support you in learning the laws of thermodynamics, the ideal gas law and kinetic theory of gases. To learn basic relationships between enthalpy, entropy and the Gibbs Free energy, and their applications in chemical and biological systems. To learn the phase equilibria and behaviours of one- and two-component systems. To learn about reaction kinetics and mechanisms.

Intended Learning Outcomes (ILO)

Upon the successful completion of this course, you should be able to :

1. Explain, determine and predict ideal gas behaviours by applying gas laws
2. Define the laws of thermodynamics and understand basic thermodynamic relationships in a given system.
3. Describe and define Gibbs Free energy and how to calculate change in entropy in both chemical and biological systems (Metabolism, DNA assembly, protein stability and DNA-protein binding.
4. Interpret and analyse systems in phase equilibria and calculate phase points, melting and boiling point elevation, Raoult's Law, Dalton's Law and Henry's Law, and osmotic pressures.
5. Evaluate the concept of thermodynamics in transport systems, active and passive transports
6. Describe and explain basic reaction kinetics, mechanisms and complex reactions, such as enzymatic reaction.

Course Content

Ideal gas behaviors and how to apply the gas law;
Laws of thermodynamics and basic thermodynamic relationships in a given system;
Gibbs Free energy and entropy in both chemical and biological systems;
Biological application of Gibbs Free energy;
Metabolism. DNA formation. Protein stability. Protein-Nuclei acid interactions.
Physical equilibria: Introduction of phase equilibrium systems.
Clausius-Clapeyron equation.
One- and two-component systems.
Colligative properties.
Thermodynamics in transport system: Active and passive transport.
Equilibrium dialysis.
Cell membrane transport.
Reaction kinetics and mechanisms:
First and second order rate kinetics.
Reaction mechanisms and rate laws.
Complex reactions. Chain reactions. Polymerization. Temperature dependence.

Assessment (includes both continuous and summative assessment)

Component	Course LO Tested	Related Programme LO or Graduate Attributes	Weighting	Team /Individual	Assess-ment rubrics
1. Tutorial Assessment:	1-6	a, b, c, e	10 %	Individual	6 Assignments See Appendix 1
2. Quizzes	1-6	a, b,c, e	30 %	Individual	2 Quizzes See Appendix 1
3. Final Examination: (2hrs; Closed Book. Require Linear Graph paper)	1-6	a, b, c, e	60 %	Individual	See Appendix 1
Total			100 %		

Mapping of Course ILOs to EAB Graduate Attributes

Course Intended Learning Outcomes	Cat	EAB's 12 Graduate Attributes*											
		(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)
	Core	◐	◐	◐		◐							

Course Intended Learning Outcomes	
1. Explain, determine and predict ideal gas behaviours by applying gas laws	a, b, c, e
2. Define the laws of thermodynamics and understand basic thermodynamic relationships in a given system.	a, b, c, e
3. Describe and define Gibbs Free energy and how to calculate change in entropy in both chemical and biological systems (Metabolism, DNA assembly, protein stability and DNA-protein binding.	a, b, c, e
4. Interpret and analyse systems in phase equilibria and calculate phase points, melting and boiling point elevation, Raoult's Law, Dalton's Law and Henry's Law, and osmotic pressures.	a, b, c, e
5. Evaluate the concept of thermodynamics in transport systems, active and passive transports	a, b, c, e
6. Describe and explain basic reaction kinetics, mechanisms and complex reactions, such as enzymatic reaction.	a, b, c, e

Formative feedback

Examination results;
Marker's report on overall examination performance will be uploaded to NTUlearn;
Quiz answers will be discussed in class

Learning and Teaching approach

Approach	How does this approach support students in achieving the learning outcomes?
Lecture	Demonstrate how to carry out a procedure such as working through a problem, use incomplete handouts which enabling you participating in class.
Tutorial	Classroom discussion sessions on tutorial questions and related topics

Reading and References

1. Thomas Engel and Philip Reid, *Thermodynamics,* 2nd Edition, Pearson Prentice Hall.
2. Ignacio Tinoco, Kenneth Sauer, James C. Wang and Joseph D. Puglisi, *Physical Chemistry: Principles and Applications in Biological sciences*, 4th Edition, Pearson Prentice Hall.

Course Policies and Student Responsibilities

General: Students are expected to complete all online activities and take all scheduled assignments and tests by due dates. Students are expected to take responsibility to follow up with course notes, assignments and course related announcements. Students are expected to participate in all tutorial discussions and activities.

Continuous assessments: Students are required to attend all continuous assessments.
Absenteeism: Continuous assessments make up a significant portion of students' course grade. Absence from continuous assessments without officially approved leave will result in no marks and affect students' overall course grade.

Academic Integrity

Good academic work depends on honesty and ethical behaviour. The quality of your work as a student relies on adhering to the principles of academic integrity and to the NTU Honour Code, a set of values shared by the whole university community. Truth, Trust and Justice are at the core of NTU's shared values.

As a student, it is important that you recognize your responsibilities in understanding and applying the principles of academic integrity in all the work you do at NTU. Not knowing what is involved in maintaining academic integrity does not excuse academic dishonesty. You need to actively equip yourself with strategies to avoid all forms of academic dishonesty, including plagiarism, academic fraud, collusion and cheating. If you are uncertain of the definitions of any of these terms, you should go to the academic integrity website for more information. Consult your instructor(s) if you need any clarification about the requirements of academic integrity in the course.

Course Instructors

Instructor	Office Location	Phone	Email
Chew Kit Wayne			kitwayne.chew@ntu.edu.sg
Teo Jye Yng			jyeyng.teo@ntu.edu.sg

Planned Weekly Schedule

Week	Topic	Course LO	Readings/ Activities
1	Basic Definitions Needed to Describe Thermodynamic Systems	1	Lecture slides/assignments, tutorial/ quizzes and final exam
2	The Ideal Gas Law and Van der Waals Equation	1	Lecture slides/assignments, tutorial/ quizzes and final exam
3	The Internal Energy and the First Law of Thermodynamics	2	Lecture slides/assignments, tutorial/ quizzes and final exam
4	Thermochemistry and Hess's Law	2	Lecture slides/assignments, tutorial/ quizzes and final exam
5	Entropy and Second Law	2	Lecture slides/assignments, tutorial/ quizzes and final exam
6	Calculating Changes in Entropy and the 3rd Law of Thermodynamics	2	Lecture slides/assignments, tutorial/ quizzes and final exam
7	Metabolism. DNA formation. Protein stability.	3	Lecture slides/assignments, tutorial/ quizzes and final exam
8	Protein-Nuclei acid interactions. Introduction of phase equilibrium systems.	3	Lecture slides/assignments, tutorial/ quizzes and final exam
9	Clausius-Clapeyron equation. One- and two-component systems. Colligative properties.	4	Lecture slides/assignments, tutorial/ quizzes and final exam
10	Active and passive transport. Equilibrium dialysis.	5	Lecture slides/assignments, tutorial/ quizzes and final exam
11	Cell membrane transport. First and second order rate kinetics. Reaction mechanisms and rate laws.	5	Lecture slides/assignments, tutorial/ quizzes and final exam
12	Complex reactions. Chain reactions. Polymerization. Temperature dependence. Enzymatic reactions	6	Lecture slides/assignments, tutorial/ quizzes and final exam
13	Revision	1-6	Lecture slides/assignments, tutorial/ quizzes and final exam

Appendix 1: Assessment Criteria (Assignments, Quizzes and Exams)

Criteria	Unsatisfactory: <40%	Borderline: 40% to 49%	Satisfactory: 50% to 69%	Very good: 70% to 89%	Exemplary: >90%
Engineering knowledge Understand the concept of thermodynamics of chemical and biological systems	Lack of understanding of the fundamentals of thermodynamics of chemical and biological systems	Partial understanding of the fundamentals of thermodynamics of chemical and biological systems	Good understanding of the fundamentals of thermodynamics of chemical and biological system	Very good & comprehensive understanding of the fundamentals of thermodynamics of chemical and biological system	Excellent understanding of the fundamentals of thermodynamics of chemical and biological system
Problem Analysis Application of thermodynamic principles to solve problems	Lack of ability to use fundamental thermodynamic principles to solve practical problems	Partial ability to use fundamental thermodynamic principles to solve practical problems	Good ability to use fundamental thermodynamic principles to solve practical problems	Very good ability to use fundamental thermodynamic principles to solve practical problems	Excellent ability to use fundamental thermodynamic principles to solve practical problems
Design/development of Solutions Solving thermodynamic problems associated to chemical & biological systems	Lack of ability to solve thermodynamic problems associated with chemical & biological systems	Partial ability to solve thermodynamic problems associated with chemical & biological systems	Good ability to solve thermodynamic problems associated with chemical & biological systems	Very good ability to solve thermodynamic problems associated with chemical & biological systems	Excellent ability to solve thermodynamic problems associated with chemical & biological systems
Modern Tool Usage Demonstration on using mathematical and computational tools to solve thermodynamic problems	Lack of ability to use modern tools to solve thermodynamic problems associated with chemical & biological systems	Partial ability to use modern tools to solve thermodynamic problems associated with chemical & biological systems	Good ability to use modern tools to solve thermodynamic problems associated with chemical & biological systems	Very good ability to use modern tools to solve thermodynamic problems associated with chemical & biological systems	Excellent ability to use modern tools to solve thermodynamic problems associated with chemical & biological systems

Appendix 2: The EAB (Engineering Accreditation Board) Accreditation SLOs (Student Learning Outcomes)

a) **Engineering knowledge:** Apply the knowledge of mathematics, natural science, engineering fundamentals, and an engineering specialisation to the solution of complex engineering problems
b) **Problem Analysis:** Identify, formulate, research literature, and analyse complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
c) **Design/development of Solutions:** Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for public health and safety, cultural, societal, and environmental considerations.
d) **Investigation:** Conduct investigations of complex problems using research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
e) **Modern Tool Usage:** Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modelling to complex engineering activities with an understanding of the limitations
f) **The engineer and Society:** Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal, and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
g) **Environment and Sustainability:** Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for the sustainable development.
h) **Ethics:** Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
i) **Individual and Team Work:** Function effectively as an individual, and as a member or leader in diverse teams and in multidisciplinary settings.
j) **Communication:** Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
k) **Project Management and Finance:** Demonstrate knowledge and understanding of the engineering and management principles and economic decision-making, and apply these to one’s own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
l) **Life-long Learning:** Recognise the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change