GUJARAT TECHNOLOGICAL UNIVERSITY (GTU)

Competency-focused Outcome-based Green Curriculum-2021 (COGC-2021)
Semester-VI

Course Title: Metallurgical Thermodynamics
(Course Code: 4362107)

Diploma programmer in which this course is offered	Semester in which offered
Metallurgy Engineering	6th Semester

1. RATIONALE

Metallurgical thermodynamics deals with the determination of the effect of surrounding on the equilibrium state of a chemical reaction system. Since most metallurgical processes involves physical and chemical changes at high temperature, the understanding of thermodynamics is a must for a metallurgist. It helps in providing information regarding changes in properties of a system during a process; matter and energy exchange during a process; feasibility and driving force of a reaction; stability and transformation of phases; phase equilibria; properties of metallurgical solutions; interfacial phenomena etc. This course is designed for diploma level which covers the theory and calculations of basic concepts and laws of thermodynamics.

2. COMPETENCY

The course content should be taught and curriculum should be implemented with the aim to develop required skills in students so that they are able to acquire following competencies:

Implement the concepts of thermodynamics to predict the feasibility of a reaction and to calculate the changes in the equilibrium state of a system during a metallurgical process.

3. COURSE OUTCOMES (COs)

The theory should be taught and practical should be performed in such a manner that students are able to acquire different learning outcomes in cognitive, psychomotor and affective domain to demonstrate following course outcomes:

CO1: Describe a thermodynamic system, its state, properties and changes occurring in it
CO2: Calculate changes in internal energy, enthalpy and entropy of a substance and a reaction applying the relevant concepts of first and second law of thermodynamics
CO3: Apply the relevant concepts of third law of thermodynamics to predict the feasibility and calculate free energy change of a reaction
CO4: Use Ellingham diagram of oxides to determine comparative stability of various compounds

4. TEACHING AND EXAMINATION SCHEME

Teaching Scheme (In Hours)			Total Credits (L+T+P/2)	Examination Scheme				
				Theory Marks		Practical Marks		Total Marks
L	T	P	C	CA	ESE	CA	ESE	
2	0	0	2	70	30*	0	0	100

(*): Out of 30 marks under the theory CA, 10 marks are for assessment of the micro-project to facilitate integration of COs and the remaining 20 marks is the average of 2 tests to be taken during the semester for the assessing the attainment of the cognitive domain UOs required for the attainment of the COs.

***Legends: L**-Lecture; **T**–Tutorial/Teacher Guided Theory Practice; **P** -Practical; **C** – Credit; **CA** – Continuous Assessment; **ESE** -End Semester Examination.*

5. AFFECTIVE DOMAIN OUTCOMES

The following sample Affective Domain Outcomes (ADOs) are embedded in many of the above- mentioned COs. More could be added to fulfill the development of this course competency.

- Conserve energy and minimize loses by calculating the energy requirements of a chemical process using the concepts of thermodynamics
- Conserve natural resources by selecting cost effective and efficient reducing agents in extractive metallurgy using Ellingham diagrams
- Conserve natural resources by predicting the behavior of matter as well as feasibility of a reaction prior to the process

6. UNDERPINNING THEORY:

Unit	Major Learning Outcomes	Topics and sub-topics
Unit – I **Introduction of Thermodynamics**	1.a. Explain different aspects of thermodynamics and its laws 1.b. Define terms involved in thermodynamics and state their significance 1.c. Describe reversible and irreversible changes and equilibrium phenomena	1.1. Introduction to thermodynamics – Definition, importance, applications, limitations 1.2. Laws of thermodynamics 1.3. Basic terms used in thermodynamics- reactor, reaction mixture, system and surrounding, types of system, state of system, equation of state, properties of system 1.4. Reversible & irreversible changes, equilibrium – definition and its types
Unit – II	2.a. Define and classify energy 2.b. Describe internal energy and	2.1. Energy – definition and its types 2.2. Internal energy, energy as a state

Energy & First law of thermodynamics	its importance as state property 2.c. State and explain first law of thermodynamics with its significance 2.d. Define Heat capacity with C_p & C_v and specific heat 2.e. Derive equations to measure enthalpy changes of a substance and chemical reaction 2.f. Explain Hess' law 2.g. Solve numerical problem on enthalpy changes at constant pressure & temperature; ΔH_r, ΔH_f and ΔH_c	property 2.3. First law of thermodynamics and its importance 2.4. Heat capacity – C_p & C_v *(exclude derivation)*, Specific heat 2.5. Enthalpy – definition, first law in terms of enthalpy, enthalpy change for a process at constant pressure, enthalpy change with temperature, enthalpy changes due to chemical reactions and its types, Hess' law 2.6. Numerical problems on enthalpy changes at constant pressure & temperature, Hess' law, ΔH_r, ΔH_f and ΔH_c
Unit-III **Second law of thermodynamics**	3.a. State and explain second law of thermodynamics 3.b. Define entropy and its importance as a state property 3.c. Describe entropy changes for reversible & irreversible process 3.d. Derive equations to measure entropy changes of a substance and chemical reaction 3.e. Derive combine expression for 1^{st} & 2^{nd} law of thermodynamics 3.f. Solve numerical problem on entropy changes	3.1. Second law of thermodynamics 3.2. Entropy – definition, as a state property 3.3. Entropy changes for reversible & irreversible process 3.4. Entropy changes of a substance and for a chemical reaction 3.5. Combined expression for 1^{st}& 2^{nd}law of thermodynamics 3.6. Numerical problems on entropy changes
Unit – IV **Free energy and third law of thermodynamics**	4.a. Explain the concept of Helmholtz free energy and Gibbs free energy 4.b. Derive equations to measure free energy change of a substance and chemical reaction 4.c. Describe free energy as a criteria of equilibrium 4.d. Stateand explain third law of	4.1. Helmholtz free energy, Gibbs free energy 4.2. Free energy change of a substance and reaction 4.3. Free energy as a criteria of equilibrium 4.4. Third law of thermodynamics 4.5. Numerical problems on change of free energy

	thermodynamics 4.e. Solve numerical problems on change of free energy	
Unit – V **Ellingham diagram**	5.a. Explain the concept of Ellingham diagram 5.b. Use Ellingham diagram determine comparative stability of various compounds 5.c. Solve numerical problems on Ellingham diagram	5.1. Concept of Ellingham diagram 5.2. Ellingham diagrams for oxides-important features 5.3. Numerical problems on Ellingham diagram

7. SUGGESTED SPECIFICATION TABLE FOR QUESTIONPAPER DESIGN

Unit No.	Unit Title	Teaching Hours	Distribution of theory marks			
			R Level	U Level	A Level	Total Marks
I	Introduction of Thermodynamics	5	6	4	0	10
II	Energy & First law of thermodynamics	8	5	7	8	20
III	Second law of thermodynamics	7	4	5	7	16
IV	Free energy and third law of thermodynamics	6	5	4	7	16
V	Ellingham diagram	2	2	2	4	8
	Total	**28**	**22**	**22**	**26**	**70**

Legends: *R = Remember; U = Understand; A = Apply and above levels (Bloom's revised taxonomy)*

Notes:

a) This specification table shall be treated as a general guideline for students and Teachers. The actual distribution of marks in the question paper may slightly vary from the above Table.

b) Ask the questions from each topic as per marks weightage. Numerical questions are to be asked only if it is specified. Optional questions must be asked from the same topic.

8. SUGGESTED STUDENT ACTIVITIES

Other than the classroom and laboratory learning, following are the suggested student-related co-curricular activities which can be undertaken to accelerate the attainment of the various outcomes in this course: Students should conduct following activities in group.

1. Search the applications of thermodynamics in various fields of metallurgy.
2. Prepare a list of various notations used in thermodynamics along with their meaning.
3. Discuss in group the universal nature of thermodynamics.
4. Prepare a table of conversion of SI units of various properties to CGS unit system.

9. SUGGESTED SPECIAL INSTRUCTIONAL STRATEGIES

Sr. No.	Unit Title	Strategies
I	Introduction of Thermodynamics	Demonstration of model. Movies/Animations. Numerical.
II	Energy & First law of thermodynamics	
III	Second law of thermodynamics	
IV	Free energy and third law of thermodynamics	
V	Ellingham diagram	

10. SUGGESTED MICRO-PROJECTS

Only one micro-project is planned to be undertaken by a student that needs to be assigned to him/her in the beginning of the semester. In the first four semesters, the micro-project is group-based. However, in the fifth and sixth semesters, it should be preferably be individually undertaken to build up the skill and confidence in every student to become problem solver so that s/he contributes to the projects of the industry. In special situations where groups have to be formed for micro-projects, the number of students in the group should not exceed three.

The micro-project could be industry application based, internet-based, workshop-based, laboratory-based or field-based. Each micro-project should encompass two or more COs which are in fact, an integration of PrOs, UOs and ADOs. Each student will have to maintain a dated work diary consisting of individual contributions in the project work and give a seminar presentation of it before submission. The total duration of the micro-project should not be less than 16 (sixteen) student engagement hours during the course. The student ought to submit a micro-project by the end of the semester to develop the industry orientedCOs.

A suggestive list of micro-projects is given here. This has to match the competency and the COs. Similar micro-projects could be added by the concerned course teacher:

1. Prepare a list of (i) state functions and path functions (ii) intensive and extensive properties.
2. Prepare a list of all the important equations of thermodynamics.
3. Select any five metals and predict their possibilities of undergoing oxidation at a particular temperature using free energy data.
4. Find out all the possible reducing agents for various metal oxide ores at different temperatures using Ellingham diagram.
5. Predict the changes occurring in a selected system in equilibrium with its surrounding when it is placed in a different surrounding.

11. SUGGESTED LEARNING RESOURCES

Sr. No.	Title of Book	Author / Editor	Publication with place, year and ISBN
1	Metallurgical Thermodynamics – Kinetics & Numericals	S. K. Dutta and A. B. Lele	S. Chand, New Delhi, 2012 (ISBN: 81-219-3964-X)
2	Textbook of Materials and Metallurgical Thermodynamics	A. Ghosh	PHI, New Delhi, 2002 (ISBN: 81-203-2091-3)
3	Essentials of Metallurgical Thermodynamics	R. H. Tupkary	Khanna Pub.; 1st Ed., New Delhi, 2016 (ISBN: 93-826-0903-2)
4	Extractive Metallurgy: Processes and Applications	S. K. Dutta, A. B. Lele and Y. B. Chokshi	PHI, New Delhi, 2018 (ISBN: 93-874-7204-3)

12. SOFTWARE/LEARNING WEBSITES

1. https://www.doitpoms.ac.uk/tlplib/ellingham_diagrams/printall.php
2. https://learnmetallurgy.com/study/thermodynamics/
3. https://archive.nptel.ac.in/
4. https://ocw.mit.edu/
5. https://ncert.nic.in/ncerts/l/kech106.pdf
6. https://chem.libretexts.org/Bookshelves/Physical_and_Theoretical_Chemistry_Textbook_Maps/Supplemental_Modules_(Physical_and_Theoretical_Chemistry)/Thermodynamics
7. https://chemed.chem.purdue.edu/genchem/topicreview/bp/ch21/chemical.php

13. PO-COMPETENCY-CO MAPPING:

Semester VI	Metallurgy Thermodynamics [Course Code: 4362107]						
	POs						
Competency & Course Outcomes	PO 1 Basic & Discipline specific knowledge	PO 2 Problem Analysis	PO 3 Design / development of solutions	PO 4 Engineering tools, Experimentation & Testing	PO 5 Engineering practices for society, Sustainability & environment	PO 6 Project Management	PO 7 Life-long learning
Competency	*Implement the concepts of thermodynamics to predict the feasibility of a reaction and to calculate the changes in the equilibrium state of a system during a metallurgical process.*						
CO1: Describe a thermodynamic system, its state, properties and changes occurring in it	3	2	1	-	1	-	-
CO2: Calculate changes in internal energy, enthalpy and entropy of a substance and a reaction applying the relevant concepts of first and second law of thermodynamics	3	3	3	-	2	-	-
CO3: Apply the relevant concepts of third law of thermodynamics to predict the feasibility and calculate free energy change of a reaction	3	3	3	-	2	-	-
CO4: Use Ellingham diagram of oxides to determine comparative stability of various compounds	3	3	3	-	2		2

*Legend: '**3'** for high, '**2**' for medium, **'1'** for low and **'-'** for no correlation of each CO with PO.*

14. COURSE CURRICULUM DEVELOPMENT COMMITTEE

GTU Resource Persons

Sr. No.	Name and Designation	Institute	Email
1.	Mr. Yakshil B. Chokshi, Lecturer Metallurgy	Government Polytechnic, Rajkot	yakshil.chokshi@gmail.com
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