

Dr. Rakesh Pant,
Gaseous and Liquid State (Sem I, BSc(Hons) Physical Chemistry)

| Time | Topics |
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| Week 1 | Kinetic theory of gases- postulates and derivation of kinetic gas equation, |
| Week 2 | Maxwell distribution of molecular velocities and its use in evaluating average, root mean square and most probable velocities and average kinetic energy. |
| Week 3 | Definition, expression, applications and temperature and pressure dependence of each one of the following properties of ideal gases: |
| Week 4 | Collision frequency, Collision diameter, Mean free path. Coefficient of viscosity, definition, units and origin of viscosity of gases, relation between mean free path and coefficient of viscosity, temperature and pressure dependence of viscosity of a gas, calculation of molecular diameter from viscosity |
| Week 5 | Barometric distribution law, its derivation and applications, alternative forms of barometric distribution law in terms of density and number of molecules per unit volume, effect of height, temperature and molecular mass of the gas on barometric distribution |
| Week 6 | Behaviour of real gases- Compressibility factor, Z , Variation of compressibility factor with pressure at constant temperature (plot of Z vs P) for different gases (H_2 , CO_2 , CH_4 and NH_3), |
| Week 7 | Cause of deviations from ideal gas behaviour and explanation of the observed behaviour of real gases in the light of molecular interactions |
| Week 8 | Revision, Assignment, Class Test |
| Week 9 | Semester Break |
| Week 10 | van der Waals (vdW) equation of state, Limitations of ideal gas equation of state and its modifications in the form of derivation of van der Waal equation, |
| Week 11 | Physical significance of van der Waals constants, application of van der Waal equation to explain the observed behaviour of real gases. |
| Week 12 | Isotherms of real gases- Critical state, relation between critical constants and van der Waals constants, correlation of critical temperature of gases |

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| | with intermolecular forces of attraction, Continuity of states, |
| Week 13 | Limitations of van der Waals equation, Reduced equation of state and law of corresponding states (statement only). |
| Week 14 | Virial equation of state-Physical significance of second and third virial coefficients, van der Waals equation expressed in virial form, |
| Week 15 | Relations between virial coefficients and van der Waals constants, Nature of liquid state, qualitative treatment of the structure of the liquid state, Physical properties of liquids-vapour pressure, its origin and definition, Vapour pressure of liquids and intermolecular forces, and boiling point |
| Week 16 | Surface tension, its origin and definition, Capillary action in relation to cohesive and adhesive forces, determination of surface tension by (i) using stalagmometer (drop number and drop mass method both) and (ii) capillary rise method, Effects of addition of sodium chloride, ethanol and detergent on the surface tension of water and its interpretation in terms of molecular interactions, Role of surface tension in the cleansing action of detergents |
| Week 17 | Coefficient of viscosity and its origin in liquids, Interpretation of viscosity data of pure liquids (water, ethanol, ether and glycerol) in the light of molecular interactions, Effects of addition of sodium chloride, ethanol and polymer on the viscosity of water, relative viscosity, specific viscosity and reduced viscosity of a solution, comparison of the origin of viscosity of liquids and gases, effect of temperature on the viscosity of a liquid and its comparison with that of a gas. |

Suggestive readings

Additional Resources:

1. Solomons, T.W.G., Fryhle, C.B., Snyder, S.A. (2017), **Organic Chemistry**, 12th Edition, Wiley.
2. Bruice, P.Y. (2020), **Organic Chemistry**, 8th Edition, Pearson.
3. Clayden, J., Greeves, N., Warren, S. (2014), **Organic Chemistry**, Oxford.
4. Nasipuri, D. (2018), **Stereochemistry of Organic Compounds: Principles and Applications**, 4th Edition, New Age International.
5. Gunstone, F.D. (1975), **Guidebook to Stereochemistry**, Prentice Hall Press.
6. Gupta, S.S. (2018), **Basic Stereochemistry of Organic Molecules**, 2nd Edition, Oxford University Press.

DISCIPLINE SPECIFIC CORE COURSE– 3 (DSC-3): Gaseous and Liquid

Credit distribution, Eligibility and Pre-requisites of the Course

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|--|---------|-----------------------------------|----------|---------------------|---------------------------------|--------------------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Gaseous and Liquid State (DSC-3: Physical Chemistry-I) | 04 | 02 | -- | 02 | Physics, Chemistry, Mathematics | -- |

Learning Objectives

The objective of this course is to develop basic and advance concepts regarding gases and liquids. It aims to study the similarity and differences between the two states of matter and reasons responsible for these. The objective of the practicals is to develop skills for working in physical chemistry laboratory. The student will perform experiments based on the concepts learnt in Physical chemistry-I course.

Learning outcomes

By the end of the course, the students will be able to:

- Derive mathematical expressions for different properties of gas and liquid and understand their physical significance.
- Apply the concepts of gas equations and liquids while studying other chemistry courses and every-day life.
- Handle stalagmometer and Ostwald viscometer properly.
- Determine the density of aqueous solutions.
- Dilute the given solutions as per required concentrations.
- Data reduction using numerical and graphical methods.

SYLLABUS OF DSC-3

UNIT – I (24 Hours)

Gaseous state

Kinetic theory of gases- postulates and derivation of kinetic gas equation, Maxwell distribution of molecular velocities and its use in evaluating average, root mean square and most probable velocities and average kinetic energy. Definition, expression, applications and temperature and pressure dependence of each one of the following properties of ideal gases: Collision frequency, Collision diameter, Mean free path. Coefficient of viscosity, definition, units and origin of viscosity of gases, relation between mean free path and coefficient of viscosity, temperature and pressure dependence of viscosity of a gas, calculation of molecular diameter from viscosity

Barometric distribution law, its derivation and applications, alternative forms of barometric distribution law in terms of density and number of molecules per unit volume, effect of height, temperature and molecular mass of the gas on barometric distribution

Behaviour of real gases- Compressibility factor, Z , Variation of compressibility factor with pressure at constant temperature (*plot of Z vs P*) for different gases (H_2 , CO_2 , CH_4 and NH_3), Cause of deviations from ideal gas behaviour and explanation of the observed behaviour of real gases in the light of molecular interactions

van der Waals (vdW) equation of state, Limitations of ideal gas equation of state and its modifications in the form of derivation of van der Waals equation, Physical significance of van der Waals constants, application of van der Waals equation to explain the observed behaviour of real gases.

Isotherms of real gases- Critical state, relation between critical constants and van der Waals constants, correlation of critical temperature of gases with intermolecular forces of attraction, Continuity of states, Limitations of van der Waals equation, Reduced equation of state and law of corresponding states (statement only).

Virial equation of state-Physical significance of second and third virial coefficients, van der Waals equation expressed in virial form, Relations between virial coefficients and van der Waals constants

UNIT – II (6 Hours)

Liquid state

Nature of liquid state, qualitative treatment of the structure of the liquid state

Physical properties of liquids-vapour pressure, its origin and definition, Vapour pressure of liquids and intermolecular forces, and boiling point

Surface tension, its origin and definition, Capillary action in relation to cohesive and adhesive forces, determination of surface tension by (i) using stalagmometer (drop number and drop mass method both) and (ii) capillary rise method, Effects of addition of sodium chloride, ethanol and detergent on the surface tension of water and its interpretation in terms of molecular interactions, Role of surface tension in the cleansing action of detergents

Coefficient of viscosity and its origin in liquids, Interpretation of viscosity data of pure liquids (water, ethanol, ether and glycerol) in the light of molecular interactions, Effects of addition of sodium chloride, ethanol and polymer on the viscosity of water, relative viscosity, specific viscosity and reduced viscosity of a solution, comparison of the origin of viscosity of liquids and gases, effect of temperature on the viscosity of a liquid and its comparison with that of a gas.

Practical component

Practicals

60 Hours

(Laboratory periods: 15 classes of 4 hours each)

1. Gases

- a. To verify the Charles law using Charles law apparatus
- b. To determine the value of universal gas constant R using the reaction
$$\text{Mg(s)} + 2\text{HCl (aq)} \rightarrow \text{MgCl}_2 \text{ (aq)} + \text{H}_2 \text{ (g)}$$

2. Surface tension measurements using stalagmometer

- a. Determine the surface tension of a liquid by drop number method.
- b. Determine the surface tension of a liquid by drop weight method.
- c. Study the variation of surface tension with different concentration of detergent solutions. Determine CMC.
- d. Study the effect of the addition of solutes on the surface tension of water at room temperature and explain the observations in terms of molecular interactions:
 - (i) sugar
 - (ii) ethanol
 - (iii) sodium chloride
- e. Study the variation of surface tension with different concentration of sodium chloride solutions.

3. Viscosity measurement using Ostwald's viscometer

- a. Determination of co-efficient of viscosity of two unknown aqueous solution.
- b. Study the variation of viscosity with different concentration of sugar solutions.
- c. Study the effect of the addition of solutes such as (i) polymer (ii) ethanol (iii) sodium chloride on the viscosity of water at room temperature and explain the observations in terms of molecular interactions

- d. Study the variation of viscosity of water with the amounts of a solute and calculate the intrinsic viscosity at room temperature.
- e. Determine the viscosity average molecular mass of the polymer (PVA) using viscosity measurements.

Essential/recommended readings

References:

Theory:

1. Atkins, P.W.; Paula, J.de. (2014), **Atkin's Physical Chemistry Ed.**, 10th Edition, Oxford University Press.
2. Ball, D. W. (2017), **Physical Chemistry**, 2nd Edition, Cengage Learning, India.
3. Castellan, G. W. (2004), **Physical Chemistry**, 4th Edition, Narosa.
4. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol 1, 6th Edition, McGraw Hill Education.

Practical:

- Khosla, B.D.; Garg, V.C.; Gulati, A. (2015), **Senior Practical Physical Chemistry**, R. Chand & Co, New Delhi.
- Kapoor, K.L. (2019), **A Textbook of Physical Chemistry**, Vol.7, 1st Edition, McGraw Hill Education.
- Garland, C. W.; Nibler, J. W.; Shoemaker, D. P. (2003), **Experiments in Physical Chemistry**, 8th Edition, McGraw-Hill, New York.

Suggestive readings

Additional Resources:

1. Moore, W.J. (1972), **Physical Chemistry**, 5th Edition, Longmans Green & Co. Ltd.
- Glasstone, S. (1948), **Textbook of Physical Chemistry**, D. Van Nostrand company, New York.

Dr. Rakesh Pant,
Chemical Energetics & Equilibria: (Sem III, BSc Physical Science)

| Time | Topics |
|---------|--|
| Week 1 | Overview of syllabus, Intensive and extensive variables; state and path functions |
| Week 2 | Isolated, closed and open systems, the concept of heat, Q, work, W, internal energy, U, and enthalpy, H. |
| Week 3 | statement of first law; enthalpy, H, relation between heat capacities for ideal gas, Joule's experiment, |
| Week 4 | calculations of Q, W, ΔU and ΔH for reversible expansion of ideal gases under isothermal conditions |
| Week 5 | Enthalpy of reactions: standard states; enthalpy of neutralization, enthalpy of ionization enthalpy of hydration, enthalpy of formation and enthalpy of combustion, |
| Week 6 | Integral enthalpy of solution, bond dissociation energy and bond enthalpy, Hess's law, Born Haber's cycle (NaCl/ KCl) |
| Week 7 | Concept of entropy; statements of the second law of thermodynamics (Kelvin and Clausius). Calculation of entropy change for reversible processes (for ideal gases) |
| Week 8 | Free Energy Functions: Gibbs and Helmholtz energy (Non-PV work and the work function); Free energy change and concept of spontaneity (for ideal gases) |
| Week 9 | Statement of the third law, qualitative treatment of absolute entropy of molecules (examples of NO, CO), concept of Entropy |
| Week 10 | Criteria of thermodynamic equilibrium. Free energy changes in a chemical reaction and equilibrium constant, exergonic, and endergonic reactions with examples such conversion of ATP to ADP or vice versa, |
| Week 11 | Revision, Assignment, Class Test |
| Week 12 | Le Chatelier's principle, relationship between K_p , K_c and K_x for reactions involving ideal gases. |
| Week 13 | Semester Break |

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| Week 14 | Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, |
| Week 15 | Ostwald's dilution law, ionization constant, and ionic product of water, |
| Week 16 | ionization of weak acids and bases, Degree of ionization, pH scale, common ion effect, |
| Week 17 | Buffer solutions, Henderson-Hasselbach equation. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle |

DISCIPLINE SPECIFIC CORE COURSE –DSC 8: Chemical Energetics and Equilibria

Credit distribution, Eligibility and Pre-requisites of the Course

| Course title & Code | Credits | Credit distribution of the course | | | Eligibility criteria | Pre-requisite of the course (if any) |
|--|---------|-----------------------------------|----------|---------------------|---|--------------------------------------|
| | | Lecture | Tutorial | Practical/ Practice | | |
| Chemical Energetics and Equilibria (DSC-8: Chemistry -III) | 04 | 02 | 0 | 02 | Class XII Pass with Physics, Chemistry, Mathematics | NIL |

Learning Objectives

The Learning Objectives of this course are as follows:

- To develop basic understanding of the chemical energetics, laws of thermodynamics and ionic equilibrium.
- To provide basic understanding of the behaviour of electrolytes and their solutions.
- To give an overview of the properties of ideal and real gases and deviation from ideal behaviour.

Learning outcomes

By the end of the course, the students will be able to:

- Explain the laws of thermodynamics, thermochemistry and equilibria.
- Illustrate the concept of pH and its effect on the various physical and chemical properties of the compounds.
- Explain and draw the concepts to predict feasibility of chemical reactions and to study the behaviour of reactions in equilibrium.

SYLLABUS OF DSC-8

Unit 1: Chemical Energetics

16 Hours

Recapitulation of Intensive and extensive variables; state and path functions; isolated, closed and open systems, concept of heat, Q, work, W, internal energy, U, and enthalpy, H.

First law

Concept of heat, Q, work, W, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities for ideal gas, Joule's experiment, calculations of Q, W, ΔU and ΔH for reversible expansion of ideal gases under isothermal conditions.

Thermochemistry

Enthalpy of reactions: standard states; enthalpy of neutralization, enthalpy of ionization enthalpy of hydration, enthalpy of formation and enthalpy of combustion, Integral enthalpy of solution, bond dissociation energy and bond enthalpy; Hess's law, Born Haber's cycle (NaCl/ KCl).

Second Law

Concept of entropy; statements of the second law of thermodynamics (Kelvin and Clausius). Calculation of entropy change for reversible processes (for ideal gases). Free Energy Functions: Gibbs and Helmholtz energy (Non-PV work and the work function); Free energy change and concept of spontaneity (for ideal gases).

Third Law

Statement of third law, qualitative treatment of absolute entropy of molecules (examples of NO, CO), concept of residual entropy

Unit 2: Chemical Equilibrium

4 Hours

Criteria of thermodynamic equilibrium. Free energy change in a chemical reaction and equilibrium constant, exergonic and endergonic reactions with examples such conversion of ATP to ADP or vice versa,, Le Chatelier's principle, relationship between K_p , K_c and K_x for reactions involving ideal gases.

Unit 3: Ionic Equilibria

10 Hours

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, Ostwald's dilution law, ionization constant and ionic product of water, ionization of weak acids and bases, Degree of ionization, pH scale, common ion effect, Buffer solutions, Henderson-Hasselbach equation. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle

Practicals components

(Laboratory periods: 60)

Chemical Energetics:

1. Determination of heat capacity of calorimeter.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
3. Determination of the enthalpy of ionization of acetic acid.
4. Determination of enthalpy of neutralization of acetic acid and ammonium hydroxide using Hess's law.
5. Determination of integral enthalpy of solution (both endothermic and exothermic)

of salts.

6. Determination of enthalpy of hydration of Copper sulphate.

Ionic equilibria:

7. Preparation of buffer solutions: (i) Sodium acetate-acetic acid or (ii) Ammonium chloride-ammonium acetate. Measurement of the pH of buffer solutions and comparison of the values with theoretical values.
8. Study the effect of addition of HCl/NaOH on pH of the buffer solutions (acetic acid, and sodium acetate).
9. Titration of strong acid with strong base using pH meter.

Essential/recommended readings

Theory:

1. Castellan, G. W. (2004), **Physical Chemistry**, Narosa.
2. Kapoor, K. L. (2015), **A Textbook of Physical Chemistry**, Vol 1, 6th Edition, McGraw Hill Education.
3. Kapoor, K. L. (2015), **A Textbook of Physical Chemistry**, Vol 2, 6th Edition, McGraw Hill Education.
4. Puri, B. R., Sharma, L. R. and Pathania M. S. (2020), **Principles of Physical Chemistry**, Vishal Publishing Co.

Practical:

1. Khosla, B. D.; Garg, V. C.; Gulati, A. (2015), **Senior Practical Physical Chemistry**, R. Chand & Co.
2. Kapoor, K. L. (2019), **A Textbook of Physical Chemistry**, Vol 7, 1st Edition, McGraw Hill Education.
3. Batra, S. K., Kapoor, V and Gulati, S. (2017) 1st Edition, **Experiments in Physical Chemistry**, Book Age series.

Note: Examination scheme and mode shall be as prescribed by the Examination Branch, University of Delhi, from time to time.