

**Q1**

- (a) State the first law of thermodynamics and express it mathematically.
- (b) What are the consequences of the first law of thermodynamics?
- (c) What is the internal energy of a system?
- (d) In your own words, define enthalpy.

**Q2**

- (a) What is the heat capacity of a system?
- (b) What are the conditions necessary for determining
  - (i) the isobaric heat capacity of a system?
  - (ii) the isochoric heat capacity of a system?
- (c) Explain the relationship between the heat capacity and the temperature of a system.

**Q3**

- (a) Describe the first law of thermodynamics with regards to a chemical reaction.
- (b) Define heat of reaction.
- (c) In terms of the change in enthalpy of a chemical system, what does Hess's law state?
- (d) Summarise Kirchhoff's law.

**Q4**

- (a) State the second law of thermodynamics and express it mathematically.
- (b) Define the entropy of a system.
- (c) Define irreversible and reversible reactions.

**Q5**

- (a) What is the entropy of a system?
- (b) Describe the change in entropy for the following basic processes:
  - (i) phase transitions
  - (ii) cooling
  - (iii) heating
- (iv) chemical reactions

**Q6**

- (a) The four fundamental thermodynamic potentials (or functions) are internal energy (U), enthalpy (H), Helmholtz free energy (F), and Gibbs free energy (G). Define each of the aforementioned thermodynamic functions.
- (b) The combined first and second laws of thermodynamics give the Gibbs equation. Derive the Gibbs equation in terms of enthalpy.
- (c) Define Maxwell relations and state why they are useful when describing a system.

**Q7**

- (a) Write the equation for the chemical potential of a gas. What does the chemical potential of a gas tell us?
- (b) What is the fugacity of a gas and why is it useful?
- (c) Summarise the relationship between the chemical potential and the fugacity of a gas.

### Q8

- The law of mass action, or law of chemical equilibrium, can be used to explain the behaviour of solutions in dynamic equilibria. In your own words, define the law of mass action.
- Define equilibrium constant.
- Using the law of mass action, write the equilibrium constant expression for the following system.

### Q9

- Define reaction isotherm and express it mathematically. What is the reaction isotherm used for?
- Describe the effect of temperature on a system at equilibrium.
- What effect does temperature have on:
  - an isobaric system?
  - an isochoric system?

### Q10

- The most common formulation of the third law of thermodynamics was presented by Max Planck. State Planck's postulate.
- Describe Nernst's heat theorem.
- What are the consequences of the third law of thermodynamics?

### Q11

- The equilibrium between the coexistence of two phases of matter depends on the temperature and pressure of the system. Using water and water vapour, describe the dependence of phase transition heat on temperature and pressure.
- What is the Clausius-Clapeyron equation and what is it used for?
- Derive the Clausius-Clapeyron equation for a liquid-vapour equilibrium interface.

### Q12

- What is the principle of Raoult's law?
- Raoult's law is only true for ideal solutions under ideal conditions. Considering this:
  - what thermodynamic considerations are necessary for a solution to obey Raoult's law?
  - give one limitation to Raoult's law.

### Q13

- Describe liquid-vapour equilibrium in an ideal or nearly ideal two-component system.
- State Henry's law and compare it to Raoult's law.
- What is the Gibbs-Konovalov theorem and what does it tell us about a two-component system?

### Q14

- What is a colligative property of a solution? Give three examples of colligative properties of a solution and state their effects.
- State Raoult's law and express it mathematically.
- Raoult's law only works for solutions with low concentrations. Why?

### Q15

- Define an electrolyte.
- Electrolytes can be classified as strong or weak. What type of substances are considered?
  - strong electrolytes?
  - weak electrolytes?
- What are the differences between a true electrolyte and a potential electrolyte?
- What is an ionogen?
- Describe an ionophore.

### Q16

- (a) What is homogeneous equilibrium?
- (b) Define a potential electrolyte.
- (c) Derive the equilibrium constant for potential electrolyte A.
- (d) For a potential electrolyte, describe what is meant by its
  - (i) dissociation constant
  - (ii) degree of dissociation
- (e) What does Ostwald's dilution law say for a potential electrolyte?

### Q17

- (a) What is a true electrolyte?
- (b) Describe, in detail, the process of a solution's formation.
- (c) What is heterogeneous equilibrium?
- (d) In your own words, define the solubility equilibrium of a substance.
- (e) What are saturated solutions? How do you know when a solution is saturated?

### Q18

- (a) With the aid of a diagram or a reaction equation, describe the autoionization of water and give the expression for the water ionisation constant.
- (b) How does the water ionisation constant depend on temperature?
- (c) What is pH? What does the pH of a solution tell us?

### Q19

- (a) What is meant by phase equilibrium?
- (b) State the conditions for phase equilibrium to be achieved.
- (c) Express Gibbs phase rule as an equation and explain its importance.
- (d) Water exists in three phases: solid, liquid and gas. Assuming that there is equilibrium between all three phases, draw an annotated phase diagram.
- (e) Define the triple point, and critical points of a phase diagram and state the significance of the critical temperature and critical pressure.

### Q20

- (a) A phase diagram is a convenient way of representing the phases of substances in a closed system as a function of temperature and pressure. Draw and annotate the phase diagram for a basic two-component system.
- (b) Define the eutectic point of a two-component system and highlight its position on your phase diagram.
- (c) What happens at the eutectic point of a system?

### Q21

- (a) What is meant by the mutual solubility of liquids?
- (b) Solubility measurement methods.

### Q22

- (a) Understanding the distribution of chemical components of a system in vapour-liquid equilibrium is essential to the design, operation and analysis of many industrial processes. In your own words, describe vapour-liquid equilibrium as it pertains to non-ideal solutions.
- (b) A chemical process that heavily relies on the distribution of chemical components in both the vapour and liquid phases is distillation. Define distillation.
- (c) What is an azeotropic mixture? Explain why it cannot be separated by fractional distillation.
- (d) How does the Gibbs-Konovalov theorem relate to azeotropic mixtures?

### Q23

- (a) Define reversible and irreversible reactions.
- (b) Describe irreversible reactions of the 1<sup>st</sup>, 2<sup>nd</sup> and n<sup>th</sup> order and write their rate equations.
- (c) Describe reversible reactions of the 1<sup>st</sup>, 2<sup>nd</sup> and n<sup>th</sup> order and write their rate equations.
- (d) How do parallel reactions and consecutive reactions differ?

### Q24

- (a) An open system is one that can exchange both matter and energy with its surroundings. Describe, in detail, the kinetics of an open reaction system in a
  - (i) capacity flow reactor
  - (ii) plug flow reactor

### Q25

- (a) Describe an elementary reaction and give the theory behind it.
- (b) Give the Arrhenius equation and state what it tells us about a system.
- (c) Define activation energy and state the limitations to Arrhenius' concept of it.
- (d) What is the collision theory?
- (e) Give the basic provisions of the transition state theory.

### Q26

- (a) Define a colloidal system and give the characteristics of the colloidal state.
- (b) What is meant by degree of dispersion?
- (c) Dispersed systems can be classified through a combination of the dispersed phase and the medium phase and how they interact. What are the different types of these systems and how do they interact?

### Q27

- (a) A method by which a colloidal dispersion can be obtained is through condensation. Describe this process.
- (b) With the aid of an annotated diagram, describe the structure of a colloidal particle.
- (c) What is the electrical double layer and how is it formed?

### Q28

- (a) List the kinetic properties of a colloidal solution.
- (b) Describe sedimentation and sedimentation rate.
- (c) What is sedimentation analysis and what can it tell us about a colloidal solution?
- (d) Explain the phenomenon of light scattering in colloidal solutions.

### Q29

- (a) Explain what happens during adsorption at an interface.
- (b) What is the difference between physical adsorption and chemical adsorption?
- (c) Define an adsorbent and an adsorbate.
- (d) What are absolute adsorption and excess adsorption and what do they tell us about the thermodynamic state of a system?

### Q30

- (a) Explain, in detail, adsorption in a gas-liquid system.
- (b) With the aid of a diagram, describe the structure and properties of liquid surfaces.
- (c) What is surface tension? Describe the ways in which it can be measured.

### Q31

- (a) Define the term 'surfactant'.
- (b) Surfactants are often described as amphiphilic. In your own words, define amphiphilicity.
- (c) Micelles are formed when surfactants aggregate.
- (d) Write Szyszkowski's equation and describe when it is used.
- (e) What is Traube's rule?

### Q32

- (a) Explain, in detail, adsorption at the solid/gas interface.
- (b) What are the differences between monolayer adsorption theory and multilayer adsorption theory?
- (c) What is the Brunauer-Emmett-Teller (BET) theory and how does it apply to systems of multilayer adsorption?

### Q33

- (a) What is capillary condensation?
- (b) Describe capillary condensation of adsorbates in porous materials.
- (c) Explain the phenomenon of hysteresis.
- (d) What is the relationship between the type of hysteresis and pore shape?

## EXAM PREPARATION MATERIALS

1. Atkins, Peter William, Julio De Paula, and James Keeler. Atkins' physical chemistry. Oxford university press, 2018.
2. Atkins' physical chemistry, 11th edition.
3. <https://drive.google.com/drive/folders/1gTsk-ajpBj-ggrfN96JBYiIKCBb0kEOr?usp=sharing>