- What is an equilibrium state?
    - Extent of reaction
    - Optimum condition
    - Least value product
    - All of the mentioned
    - Answer: a
    - Clarification: The extent to which a chemical reaction may proceed under a given set of conditions is given by the equilibrium state.

- What is the driving force in a reaction?
    - Energy given
    - Energy released
    - Free energy
    - None of the mentioned
    - Answer: c
    - Clarification: The driving force of the reaction is the change in free energy, which is related to the equilibrium constant (K).

- What should be the free energy so that reaction is spontaneous?
    - Positive
    - Negative
    - Neutral
    - None of the mentioned
    - Answer: b
    - Clarification: If the free energy change is negative the reaction is spontaneous and becomes more favourable with increasing (-dF); on the other hand if the free energy change is positive and greater than 10 kg-cal per mole the reaction is not suitable for practical application.

- What is the heat of reaction for hydrolysis of Ethyl Acetate?
    - Greater than zero
    - Less than zero
    - Zero
    - None of the mentioned
    - Clarification: In hydrolysis of ethyl acetate, the equilibrium position was shown to be independent of the temperature. A calculation of the heat of reaction by the method of bond energies gives a value of zero, since the bonds broken are of the same type as the bonds formed.

- What is meant by ‘Z’ in Arrhenius equation?
    - Energy of activation
    - Gas constant
    - Probability factor
    - Frequency of collision
    - Answer: d
    - Clarification: In Arrhenius equation, E is the energy of activation, R the gas constant, Z the frequency of collision at unit concentration of reactants, and P a probability factor.

- A battery is an arrangement of electrolytic cells.
    - True
    - False
    - Answer: b
    - Clarification: A battery is not an arrangement of electrolytic cells, but an arrangement of electrochemical cells. An electrochemical cell is one which converts chemical energy into electrical energy whereas an electrolytic cell is one which converts electrical energy into chemical energy. Since batteries convert chemical energy to electrical energy, it is an arrangement of electrochemical cells.

- Which of the following is not a requirement for a useful battery?
    - It should be light and compact
    - It should have a reasonable life span
    - It should ideally have a constant voltage throughout its lifespan
    - It should supply Alternating Current(AC)
    - Answer: d
    - Clarification: A useful battery is expected to be light and compact to be easily transported. It is expected to have a reasonable lifespan to justify its usage. Its voltage should not vary appreciably during usage so that it doesn't adversely affect the circuit it is used in. A battery supplies Direct Current(DC) and not Alternating Current(AC).

- Which of the following statements is true regarding a primary cell?
    - The electrode reactions can be reversed
    - It can be recharged
    - An example of a primary cell is a mercury cell
    - An example of a primary cell is a nickel-cadmium storage cell
    - Answer: c
    - Clarification: A primary cell is one in which the electrode reactions occur only once and cannot be reversed by applying electrical energy. Therefore, primary cells cannot be recharged. A mercury cell is an example of a primary cell, whereas a nickel-cadmium storage cell is an example of a secondary cell.

- Secondary cells are also called storage cells.
    - True
    - False
    - Answer: a
    - Clarification: Secondary cells are those cells in which the electrode reaction can be reversed by applying an electrical energy. Therefore, they can be used to store electrical energy. So, they are also known as storage cells.

- Which of the following is used as an anode in a dry cell?
    - Zinc
    - Graphite
    - Mercury(II) oxide
    - Nickel
    - Answer: c
    - Clarification: A dry cell is constructed using zinc and graphite. It consists of a zinc cylinder through whose centre passes a graphite rod. The zinc cylinder acts as an anode, whereas the graphite rod acts as a cathode.

- Why do leak proof dry cells have an iron or steel sheet covering the zinc cylinder?
    - It increases the potential difference between the anode and cathode
    - It acts as a barrier around the zinc cylinder which can develop holes during use
    - It makes it waterproof
    - It prevents the leakage of current
    - Answer: b
    - Clarification: In a dry cell, zinc loses electrons and the zinc ions
    - dissolve into the electrolyte. As a result, the zinc cylinder of the dry cell develops holes as it is used. To prevent the leakage of electrolyte through these holes, an iron or steel sheet is used to cover the cylinder.

- Which of the following is the electrolyte used in a dry cell?
    - Ammonium chloride
    - Manganese dioxide
    - Potassium hydroxide
    - Sulphuric acid
    - Answer: a
    - Clarification: The electrolyte in a dry cell is ammonium chloride in the form of a moist paste placed next to the zinc anode. In some dry cells marketed as “heavy-duty”, the ammonium chloride is replaced by zinc chloride.

- Which of the following scientists invented the first dry cell?
    - Carl Gassner
    - Nikola Tesla
    - Antione Lavoisier
    - Georges Leclanché
    - Answer: a
    - Clarification: In the year 1886, Carl Gassner obtained a German patent on a variant of the wet Leclanché cell, which can be known as the dry cell because it did not have a liquid electrolyte. Instead, a mixture of ammonium chloride and plaster of paris was used.

- A fuel cell is a type of electrochemical cell.
    - True
    - False
    - Answer: a
    - Clarification: Fuel cells are the devices which convert the energy produced during the combustion of fuels (chemical energy) like hydrogen, methane, methanol etc. directly into electrical energy. Hence, a fuel cell is a type of electrochemical cell.
- Which of the following is used as an electrolyte in an H_2-O_2 fuel cell?
    - KOH
    - NH_4OH
    - $Fe(OH)_2$
    - $Cu(OH)_2$
    - Answer: a
    - Clarification: The general design of the H2-O2 fuel cell consists of porous carbon electrodes containing suitable catalysts (generally finely divided platinum and palladium) incorporated in them. Concentrated KOH or NaOH solution is placed between the electrodes to act as the electrolyte.

- Which of the following can be used as fuel in a fuel cell?
  - Nitrogen
  - Argon
  - Hydrogen
  - Helium
  - Answer: c
  - Clarification: Hydrogen is the simplest element. It is also abundantly available in the universe. Hydrogen is high in energy, yet an engine that burns pure hydrogen produces almost no pollution. Hence, it used in a fuel cell.

- Which of the following is not a fuel cell?
  - PEM cell
  - Direct methanol cell
  - Solid oxide cell
  - Daniell cell
  - Answer: d
  - Clarification: Polymer electrolyte membrane (PEM) cell, direct methanol cell and solid oxide cell are all types of fuel cells. Daniell cell is a primary galvanic cell with a copper cathode and a zinc- amalgam anode. Daniell cell is a reversible cell.

- Which of the following is not produced in an H_2-O_2 fuel cell?
  - Electricity
  - Pollutants
  - Heat
  - Water
  - Answer: b
  - Clarification: Fuel cells convert the chemical energy of fuel into electricity through combustion. Since combustion is an exothermic reaction, heat is evolved. The overall reaction in an H2-O2 cell is: 2H2 (g) + O2 (g) → 2H2O (l) Thus, water is also produced.

- Which of the following is supplied to the cathode of a fuel cell?
  - Hydrogen
  - Nitrogen
  - Oxygen
  - Chlorine
  - Answer: c
  - Clarification: A fuel cell is composed of an anode, cathode, and an electrolyte membrane. A typical fuel cell works by passing hydrogen through the anode of a fuel cell and oxygen through the cathode.

- Who invented the first fuel cell?
  - Francis Bacon
  - Thomas Grubb
  - Leonard Niedrach
  - William Grove
  - Answer: d
  - Clarification: The first fuel cell was conceived by Sir William Robert Grove in 1839. He mixed hydrogen and oxygen in the presence of an electrolyte and produced electricity and water. The fuel cell he made used similar materials to today's phosphoric acid fuel cell.

- What is the maximum theoretical energy efficiency of a fuel cell?
    - 100%
    - 69%
    - 50%
    - 83%
    - Answer: d
    - Clarification: E°cell of an H_2-O_2 fuel cell = 1.23 V and ΔH=-285.8 kJ mol-1 ΔG = -n x F x E°cell = -2 x 96500 x 1.23
      = -237390 J mol-1
      = -237.390 kJ mol-1
      Efficiency = ΔG/ΔH x 100
      = -237.390/-285.8 x 100
      = 83%.

- Which of the following statements regarding fuel cells is false?
    - Because of continuous supply, fuel cells never become dead
    - They do not cause pollution
    - Fuel cells have 100% efficiency practically
    - The cost of catalysts needed for the electrode reactions is high
    - Answer: c
    - Clarification: Theoretically, the fuel cells are expected to have an efficiency of 100%. However, practically they give efficiency of 60- 70%. Still, they are much superior to the thermal power plants in which fuels are burnt to produce heat which then changes water into steam to run the turbine. Such a power plant does not have an efficiency of more than 40%.

- Which of the following are the common ways to produce H_2 gas in a fuel cell?
    - Coal and biomass gasification
    - Electrolysis and absorption
    - Steam reforming and electrolysis
    - Electromagnetism and steam reforming
    - Answer: c
    - Clarification: Since hydrogen does not exist as a gas on Earth, it must be separated from other elements. Hydrogen atoms can be separated from water, natural gas molecules or biomass. The two most common ways to produce hydrogen are steam reforming (using high-temperature steam to produce hydrogen from natural gas) and electrolysis (splitting water).

- A galvanic cell converts electrical energy into chemical energy.
    - True
    - False
    - Answer: b
    - Clarification: A galvanic cell is a type of electrochemical cell that converts chemical energy into electrical energy. The electrochemical cell which converts electrical energy into chemical energy is called electrolytic cell.

- Who invented the galvanic cell?
  - Galvani and Volta
  - Henry Cavendish
  - Joseph Priestley
  - Antoine Lavoisier
  - Answer: a
  - Clarification: Electrochemical cells are also called galvanic or voltaic cells, after the names of Luigi Galvani and Alessandro Volta who were the first to perform experiments on the conversion of chemical energy into electrical energy.

- Which of the following electrolytes is not preferred in a salt bridge?
  - KCl
  - KNO_3
  - NH_4NO_3
  - NaCl
  - Answer: d
  - Clarification: In a salt bridge, the electrolytes like KCl, KNO3 or NH4NO3 are preferred because their ions have almost equal transport number, viz., 0.5, i.e., they move with almost the same speed when an electric current flows through them.

- Which of the following is false regarding galvanic cells?
  - It converts chemical energy into electrical energy
  - The electrolytes taken in the two beakers are different
  - The reactions taking place are non-spontaneous
  - To set up this cell, a salt bridge is used
  - Answer: c
  - Clarification: Galvanic cells are used to convert chemical energy into electrical energy. Two electrodes are usually set up in two separate beakers. The electrolytes taken in the two beakers are different. Galvanic cells are based upon spontaneous redox reactions. A salt bridge is used to set up this cell.

- The electrode on which oxidation occurs is called the anode. True or False?
  - True
  - False
  - Answer: a
  - Clarification: An anode is an electrode where oxidation takes place. An anode is a negative pole in a galvanic cell. In an electrolytic cell, the anode acts as the positive pole. Cathodes are electrodes where reduction takes place.

- A cell is prepared by dipping a copper rod in 1 M $CuSO_4$ solution and an iron rod in 2 M $FeSO_4$ solution. What are the cathode and anode respectively?
  - Cathode: Iron, Anode: Copper
  - Cathode: Copper, Anode: Iron
  - Cathode: Iron, Anode: Iron
  - Cathode: Copper, Anode: Copper
  - Answer: b
  - Clarification: The given cell is represented as:
  - Fe (s) | FeSO4 (2 M) || CuSO4 (1 M) | Cu (s) Since the E° of iron

- Which of the following is the correct order of reactivity of metals?
    - Zn > Mg > Fe > Cu > Ag
    - Zn > Mg > Fe > Ag > Cu
    - Mg > Zn > Fe > Ag > Cu
    - Mg > Zn > Fe > Cu > Ag
    - Answer: d
    - Clarification: Greater the oxidation potential of metal, the more easily it can lose electrons and hence greater is its reactivity. As a result, a metal with greater oxidation potential can displace metals with lower oxidation potentials from their salt solutions. Hence, the correct order of reactivity is Mg > Zn > Fe > Cu > Ag.

- Which of the following is a correct method to calculate the EMF of a galvanic cell?
    - Standard EMF of the cell = [Standard reduction potential of the reduction half reaction] + [Standard reduction potential of the oxidation half reaction]
    - Standard EMF of the cell = [Standard oxidation potential of the oxidation half reaction] – [Standard reduction potential of the reduction half reaction]
    - E°cell = E°cathode – E°anode
    - Standard EMF of the cell = [Standard reduction potential of the right-hand side electrode] + [Standard reduction potential of the left-hand side electrode]
    - Answer: c
    - Clarification: The correct methods to calculate the EMF of a galvanic cell are:Standard EMF of the cell = [Standard reduction potential of the reduction half reaction] – [Standard reduction potential of the oxidation half reaction].Standard EMF of the cell = [Standard oxidation potential of the oxidation half reaction] + [Standard reduction potential of the reduction half reaction].E°cell = E°cathode – E°anode. Standard EMF of the cell = [Standard reduction potential of the right hand side electrode] – [Standard reduction potential of the left hand side electrode].

- What is the EMF of a galvanic cell if E°cathode = 0.80 volts and E°anode = -0.76 volts?
    - 1.56 volts
    - 0.04 volts
    - -1.56 volts
    - -0.04 volts
    - Answer: a Clarification: Given, E°cathode = 0.80 volts E°anode = -0.76 volts E°cell = E°cathode – E°anode E°cell = 0.80 – (-0.76) E°cell = 1.56 volts.

- What is the EMF of a galvanic cell if the standard oxidation potential of the oxidation half-reaction is 0.64 volts and the standard reduction potential of the reduction half-reaction is 0.48 volts?
    - 1.48 volts
    - 1.12 volts
    - 1.36 volts
    - 0.96 volts
    - Answer: b
    - Clarification: Given,
    - Standard oxidation potential of the oxidation half reaction = 0.64 volts Standard reduction potential of the reduction half reaction = 0.48 volts

    Standard EMF of the cell = [Standard oxidation potential of the oxidation half reaction] + [Standard reduction potential of the reduction half reaction]= 0.64 + 0.48= 1.12 volts.

- What is the EMF of a galvanic cell if the standard reduction potential of the reduction half-reaction is -0.38 volts and the standard reduction potential of the oxidation half-reaction is 0.52 volts?
    - -0.9 volts
    - -0.6 volts
    - 0.9 volts
    - 0.6 volts
    - Answer: a
    - Clarification: Given, Standard reduction potential of the reduction half reaction = -0.38 volts Standard reduction potential of the oxidation half reaction = 0.52 volts Standard EMF of the cell = [Standard reduction potential of the reduction half reaction] – [Standard reduction potential of the oxidation half reaction] = -0.38 – (0.52) = -0.9 volts.

- What is the standard reduction potential of the cathode of a galvanic cell if the standard EMF of the cell and the standard reduction potential of the anode are 2.71 and -2.37 respectively?
    - 0.68 volts
    - -0.68 volts
    - -0.34 volts
    - 0.34 volts
    - Answer: d
    - Clarification: Given, Standard EMF of the cell = E°cell = 2.71 volts Standard reduction potential of the anode = E°anode = -2.37 volts E°cell = E°cathode – E°anode E°cathode = E°cell + E°anode = 2.71 + (-2.37) = 0.34 volts.

- The standard oxidation potential of Ni/Ni2+ electrode is 0.3 V. If this is combined with a hydrogen electrode in acid solution, at what pH of the solution with the measured e.m.f. be zero at 25°C? (Assume [Ni2+] = 1M)
    - 5.08
    - 4
    - 4.5
    - 5.25
    - Answer: a
    - Clarification: Given, Standard oxidation potential of Ni/Ni2+ electrode, E°OP = 0.3 V, Ni ⟶ Ni2+ + 2e 2H+ + 2e ⟶ H2
      E°cell = E° (OP) + E° (RP)
      E° (cell) = 0.3 + 0.0 = 0.3 V
      According to Nernst equation, E (cell) = E°(cell) + (frac{0.059}{2})
      log10([H+]2 / [Ni]+2)
      0 = 0.3 + (frac{0.059}{2})log10([H+]2)
      -log ([H+]) = 5.08 pH = 5.08.

- Calculate the equilibrium constant for the reaction Fe + CuSO4 ⇌ FeSO4 + Cu at 25°C. (Given E°(OP/Fe) = 0.5 V°, E°(OP/Cu) = -0.4 V)
    - 3.46 × 1030
    - 3.46 × 1026
    - 3.22 × 1030
    - 3.22 × 1026
    - Answer: c

      Clarification: The cell reaction shows oxidation of Fe and reduction of Cu2+ Therefore for the reaction, Fe + CuSO4 ⇌ FeSO4 + Cu E°(cell) = E°(OP/Fe) + E°(RP/Cu) E°(cell) = 0.5 + 0.4 = 0.9 V We have, E° = (frac{0.059}{2})log10 Kc 0.9 = (frac{0.059}{2})log10 Kc Kc = 3.22 × 1030.

- Calculate the e.m.f. of the half-cell given below.
- Pt, H_2 | HCl at 1-atmosphere pressure and 0.1 M. Given, E°(OP) = 2 V.
    - 4 V
    - 5.6 V
    - 3.4 V
    - 5.4 V
    - Answer: d
    - Clarification: Given, E°(OP) = 2 V, H2 → 2H+ + 2e E(OP) = E°(OP) – (frac{0.059}{2})log10([H+]2/ P (H2)) E(OP) = 2 – (frac{0.059}{2})log10 (0.022 / 1) = 5.4 V.

- The equilibrium constant for a cell reaction, Cu(g) + 2Ag+(aq) → Cu2+(aq) + 2Ag (s) is 4 × 1016. Find E° (cell) for the cell reaction.
    - 0.63 V
    - 0.49 V
    - 1.23 V
    - 3.24 V
    - Answer: b Clarification: Given, equilibrium constant Kc = 4 × 1016 E° (cell) = (frac{0.059}{2})log10 Kc E°(cell) = (frac{0.059}{2})log10 (4 × 1016)=0.49V.

- What is the correct Nernst equation for M2+ (aq) + 2e+ → M (s) at 45°C?
    - E°(M2+/M) + 0.315log10 (1 / [M]+2)
    - E° (M2+/M) + 0.0425log10 (1 / [M]+2)
    - E° (M2+/M) + 0.0315log10 (1 / [M]+2)
    - E° (M2+/M) + 0.0326log10 (1 / [M]+2)
    - Answer: c Clarification: Given, Temperature T = 45°C
      We know, n (number of electrons transferred) = 2 According to Nernst equation,
      E(M2+/M) = E° (M2+/M) +2.303(frac{RT}{nF})log10 (M / [M]+2)
      Concentration of [M] is taken to be 1 The equation becomes: E° (M2+/M)
      +2.303 (frac{RT}{nF})log10 (1/[M]+2) E(M2+/M) = E° (M2+/M) +2.303 ×
      (frac{8.314 times 318}{2 times 96500})log10 (1 / [M]+2) =E° (M2+/M) +
      0.0315log10 (1 / [M]+2).

- The e.m.f and the standard e.m.f of a cell in the following reaction is 5 V and 5.06 V at room temperature, Ni(s) + 2Ag+(n) → Ni2+(0.02M) + 2Ag(s). What is the concentration of Ag+ ions?
    - 0.0125 M
    - 0.0314 M
    - 0.0625 M
    - 0.0174 M
    - Answer: d
    - Clarification: Given, Temperature T = 298K Concentration of Ni2+ = (0.02M) E(cell) = E°(cell) – (frac{0.059}{n})log10 (Anode / Cathode) 5 = 5.06 – (frac{0.059}{2})log10(0.02 / [Ag+] 2) [Ag+]2 = 0.0174 M.

- What is the value of universal gas constant in Nernst equation when the potential is given in volts?
    - 8.314 J $mol^{-1}K^{-1}$
    - 0.0821 L atm $mol^{-1}K^{-1}$
    - 8.205 m3 atm $mol^{-1}K^{-1}$
    - 1.987 cal $mol^{-1}K^{-1}$
    - Answer: a
    - Clarification: The universal gas constant is denoted by R and is expressed in units of energy per temperature per mole. Since volts is the SI-Unit of potential, R must also be taken in SI-Units which is J mol-1K-1.

- First law of thermodynamics deals with
    - Conservation of mass
    - Conservation of momentum
    - Conservation of energy
    - Conservation of pressure
    - Answer: c
    - Clarification: First law corresponds to the law of conservation of energy. It states that energy can neither be created nor destroyed, but can be transformed from one form to the other. It follows the principle of heat transfer and energy transfer.

- Equation of the first law of thermodynamics is

    - Internal Energy= Heat added into work done
    - Internal Energy= Heat rejected into work done
    - Internal Energy= Heat added divided by work done
    - Internal Energy=Heat added plus work done
    - Answer: d
    - Clarification: It is a thermodynamic expression which gives a relationship between internal energy, heat and work done. Work done on the system is positive, and work done by the system is negative. The standard unit of all these quantities is Joule.

- An increase in enthalpy leads to an increase in
    - Increase in pressure
    - Increase in volume
    - Increase in internal energy
    - Increase in mass
    - Answer: c
    - Clarification: When the temperature increases, the amount of molecular interactions also increases. Using the equation from the first law of thermodynamics, internal energy also increases with the increase in temperature. Thus, increase in enthalpy leads to an increase in internal energy.

- What reaction takes place during photosynthesis?
    - Exothermic reaction
    - Endothermic reaction
    - Redox reaction
    - Combustion reaction
    - Answer: b Clarification: Photosynthesis takes place by absorbing heat and energy from the surroundings. Since, endothermic reaction is a reaction in which the system absorbs heat from its surroundings, the reaction that takes place during photosynthesis is an endothermic reaction.