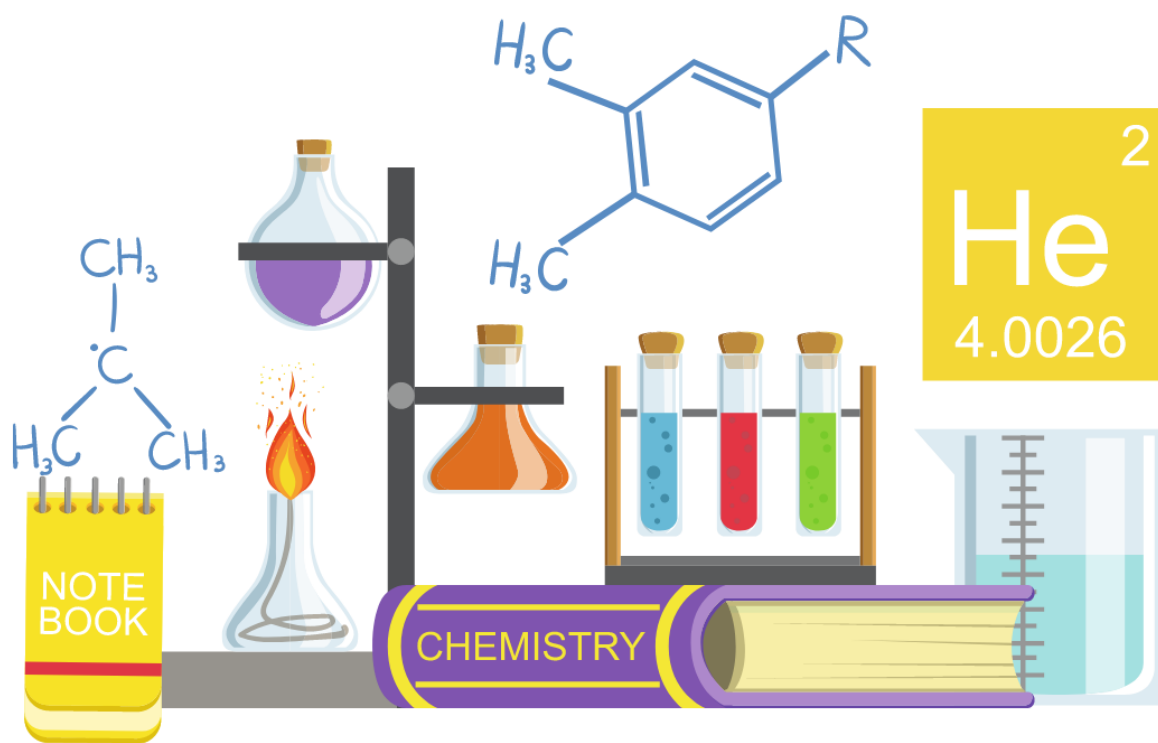# IB Chemistry HL Paper 1 Question Bank

Chemistry
Higher level
Paper 1

1 hour

Instructions to candidates
1. Answer all the questions.
2. For each question, choose the answer you consider to be the best and indicate your choice on the answer sheet provided.
3. A clean copy of the chemistry data booklet is required for this paper.
4. The maximum mark for this examination paper is **[40 marks]**

5. **How do the following properties change down Group 16 of the periodic table?**
   A. Atomic radius increases, Ionic radius decreases
   B. Atomic radius increases, Ionic radius increases
   C. Atomic radius decreases, Ionic radius increases
   D. Atomic radius decreases, Ionic radius decreases

Answer: B

The atomic and ionic radii increase down the group. This is due to the addition of a new shell at each successive element on moving down the group.

6. **Which series represents atoms in order of increasing atomic radius?**
   A. K < Na < Si
   B. Si < Na < K
   C. Na < Si < K
   D. K < Si < Na

Answer: B

The atomic size increases down the group. Na and K belong to the same group. Hence Na<K. Also atomic size decreases along a period and Na and Si belong to the same period. ∴ Na>Si. On combining, the final order is Si<Na<K

7. **How does a sodium atom form the most stable ion?**
   A. Atom gains an electron to form a negative ion
   B. Atom loses electron to form a positive ion
   C. Atom loses proton to form a negative ion
   D. Atom gains proton to form a positive ion

Answer: B

The most stable form of the sodium atom is Na^+ and for it to come to this stable state, it needs to lose an electron from its outermost shell. Atoms do not lose protons to become ions as they are present inside the nucleus.

8. **Which of these statements are properties of transition metals?**
   A. High melting points
   B. Low densities
   C. Insulators of heat and electricity
   D. Soft in nature

Answer: A

Transition metals are known for having high melting points in addition to high densities, electrical and heat conductivity, variable oxidation states and their ability to form coloured compounds.

9. **How many sigma (σ) and pi (π) bonds are present in ethyne, C_2H_2?**
   A. Sigma bonds: 2   Pi bonds: 2
   B. Sigma bonds: 2   Pi bonds: 3
   C. Sigma bonds: 3   Pi bonds: 2
   D. Sigma bonds: 3   Pi bonds: 3

Answer: C

Each atom is connected by at least one single bond which will be counted as σ bonds and the rest are π bonds. Hence there are 3 sigma (σ) bonds and 2 pi (π) bonds in ethyne.

10. **Which statement is correct about a catalyst?**
    A. Catalysts initiate reactions
    B. Catalysts increase the activation energy
    C. Catalysts increases the yield of the reaction
    D. Catalysts increase the rate of the reaction

Answer: D

Catalysts only increase the rate of the reaction by lowering the activation energy. They do not have the properties of increasing the yield of the reaction or initiating reactions.

11. **Which species has a square planar molecular geometry?**
    A. CH_2O
    B. CH_4
    C. C_2H_4
    D. CH_4O

Answer: B

CH_4O is the only molecule that has a hydrogen bonding between O and H. The other molecules have bonds between C and H which are not considered hydrogen bonds. Hydrogen bonds results from the attractive force between a hydrogen atom covalently bonded to a very electronegative atom such as a N, O, or F atom

12. **Which compound makes unpolluted rain acidic in nature?**
    A. Nitrogen oxides
    B. Sulfur dioxide

C. Carbon dioxide
D. Methane

Answer: C
Unpolluted rain has a slightly acidic pH of 5.6, because carbon dioxide and water in the air react together to form carbonic acid, a weak acid.

13. Which of the following compounds is polar?
A. Cl_2
B. CO_2
C. CH_4
D. H_2O

Answer: A
Water (H_2O) is polar because of the bent shape of the molecule. The shape means most of the negative charge from the oxygen on one side of the molecule and the positive charge of the hydrogen atoms is on the other side of the molecule.

14. Which of the following increases the rate of reaction?
A. Decreasing temperature
B. Increasing concentration
C. Adding a catalyst
D. Decreasing collision frequency

Answer: B
With an increase in concentration, the number of molecules with the minimum required energy will increase, and therefore the rate of the reaction will increase. Adding a catalyst, decreasing the temperature and collision frequency will reduce the activation energy.

15. The reaction A --> B has a rate constant of 0.02 s^-1. If the initial concentration of A is 0.5 M and the reaction is first order, what is the concentration of A after 20 seconds?
A. 0.05 M
B. 0.10 M
C. 0.15 M
D. 0.20 M

Answer: D
*The concentration of A after time t is given by the equation [A] = [A]_0 * e^(-kt), where [A]_0 is the initial concentration of A, k is the rate constant, and t is time. Plugging in the given values, we get [A] = 0.5 * e^(-0.02*20) = 0.20 M.*

16. Which of the following compounds is most likely to undergo E1 elimination?
    A. $CH_3CH_2CH_2OH$
    B. $(CH_3)_2CHCH_2OH$
    C. $CH_3CH(OH)CH_3$
    D. $CH_3CH_2CH(OH)CH_3$

Answer: B
E1 elimination occurs when a carbocation is formed as an intermediate. The stability of the carbocation determines the rate of the reaction. In this case, $(CH_3)2CHCH_2OH$ has a tertiary carbocation intermediate, which is more stable than the primary carbocation intermediate in the other options.

17. The standard enthalpy change of combustion of ethanol is -1367 kJ/mol. What is the standard enthalpy of formation of ethanol?
    A. -277 kJ/mol
    B. -290 kJ/mol
    C. -304 kJ/mol
    D. -328 kJ/mol

Answer: D
The standard enthalpy of formation of a compound is the enthalpy change when 1 mole of the compound is formed from its elements in their standard states. The relationship between standard enthalpies of combustion and standard enthalpies of formation is given by Hess's law: ΔHf = ΣnΔHc(products) - ΣnΔHc(reactants). Plugging in the values, we get ΔHf = (-1367 kJ/mol) - [(3*(-393.5 kJ/mol)) + (2*(-285.8 kJ/mol))] = -328 kJ/mol.

18. What is the empirical formula of a compound that contains 0.30 moles of carbon, 0.60 moles of hydrogen, and 0.10 moles of oxygen?
    A. CH_2O
    B. C_2H_5O
    C. $C_3H_6O_2$
    D. $C_5H_{10}O_5$

Answer: A
The empirical formula is the simplest whole number ratio of atoms in a compound, so divide each mole value by the smallest mole value, which is 0.10: C 0.30/0.10 = 3, H 0.60/0.10 = 6, O 0.10/0.10 = 1. The empirical formula is therefore CH_2O.

19. What is the oxidation state of chlorine in $HClO_4$?
    A. +1
    B. +3
    C. +5

D. +7

Answer: D

The sum of the oxidation states of all atoms in a molecule or ion is equal to the charge of the molecule or ion. Since H has an oxidation state of +1 and O has an oxidation state of -2, the oxidation state of Cl must be +7 to balance out the charge.

20. Which of the following reactions has the slowest rate of reaction?
    A. $A + B \rightarrow C$
    B. $2A \rightarrow B$
    C. $A + 2B \rightarrow 3C$
    D. $2C \rightarrow A + B$

Answer: D

The rate of a chemical reaction is determined by the rate-determining step, which is usually the slowest step. In this case, the reaction with the slowest rate of reaction is likely to have the slowest rate-determining step. The correct answer is (d) because it is a reverse reaction, which is generally slower than forward reactions.

21. What is the activation energy for a reaction that has a rate constant of 2.5×10^{-3} s^{-1} at 298 K and 3.0×10^{-3} s^{-1} at 308 K?
    A. 11.3 kJ/mol
    B. 16.5 kJ/mol
    C. 21.8 kJ/mol
    D. 27.1 kJ/mol

Answer: B

The activation energy (Ea) can be calculated using the Arrhenius equation, $k = Ae^{(-Ea/RT)}$. Taking the natural logarithm of this equation gives $ln(k) = -Ea/RT + ln(A)$. By plotting $ln(k)$ vs. 1/T, the slope of the line is equal to -Ea/R, where R is the gas constant. Using the data given, the slope of the line is $(ln(3.0 \times 10^{-3}) - ln(2.5 \times 10^{-3}))/(1/308 - 1/298) = 2195.5$ K. Multiplying this value by R (8.31 J/mol K) gives 18.2 kJ/mol. Therefore, the correct answer is (b).

22. Which of the following is the strongest acid?
    A. HF
    B. HCl
    C. HBr
    D. HI

Answer: D

The strength of an acid is determined by its tendency to donate a proton (H^+). The strength of hydrogen halides increases down the group due to decreasing bond strength, so HI is the strongest acid.

23. **Which of the following is a type of intermolecular force that results from the temporary uneven distribution of electrons in a molecule?**
    - A. Dipole-dipole forces
    - B. Hydrogen bonding
    - C. London dispersion forces
    - D. Ionic bonding

Answer: C

London dispersion forces result from the temporary uneven distribution of electrons in a molecule, which creates temporary dipoles that can induce dipoles in neighboring molecules.

24. **A student titrated a solution of HCl with NaOH. The initial volume of HCl was 25 mL and it required 15 mL of 0.1 M NaOH to reach the equivalence point. What is the concentration of HCl?**
    - A. 0.06 M
    - B. 0.15 M
    - C. 0.25 M
    - D. 0.35 M

Answer: C

The equation for the reaction between HCl and NaOH is $HCl + NaOH \rightarrow NaCl + H_2O$. At the equivalence point, the moles of HCl will equal the moles of NaOH. Therefore, (0.1 M) x (15 mL) = (C HCl) x (25 mL), where C HCl is the concentration of HCl. Solving for C HCl gives a concentration of 0.25 M.

25. **A sample of gas has a volume of 3.5 L at a pressure of 2.0 atm and a temperature of 25°C. If the pressure is increased to 3.5 atm and the temperature is held constant, what is the new volume of the gas?**
    - A. 0.71 L
    - B. 1.43 L
    - C. 2.86 L
    - D. 4.67 L

Answer: A

This problem can be solved using Boyle's Law, which states that the pressure and volume of a gas are inversely proportional, assuming constant temperature. Using the equation $P_1V_1 = P_2V_2$, where P1, V1, and P2 are the initial pressure, volume, and final pressure, respectively, we can solve for V2, the final volume. $V2 = (P_1V_1)/P_2 = (2.0\ atm)(3.5\ L)/(3.5\ atm) = 2.0\ L$.

26. **Which of the following is an example of an isomer?**
    - A. $CH_2CH_2CH_2OH$ and $CH_3CH_2OCH_3$
    - B. CH_3CH_2COOH and CH_3COCH_3

C. H_2O and H_2O_2
D. NaCl and NaBr

Answer: A

$CH_3CH_2CH_2OH$ and $CH_3CH_2OCH_3$. Isomers are molecules that have the same molecular formula but different structures. In this case, the two molecules have the same number and types of atoms, but the arrangement of the atoms is different.

27. **What is the rate constant for the reaction A + B → C if the rate of disappearance of A is 1.5×10^{-2} mol L^{-1} s^{-1} and the initial concentration of A is 0.2 M and that of B is 0.1 M?**
    A. 3.75×10^{-4} L mol^{-1} s^{-1}
    B. 7.5×10^{-4} L mol^{-1} s^{-1}
    C. 1.5×10^{-3} L mol^{-1} s^{-1}
    D. 3.0×10^{-3} L mol^{-1} s^{-1}

Answer: B

The rate law for this reaction is rate = k[A][B]. Therefore, the rate constant can be calculated by dividing the rate of reaction by the product of the initial concentrations of A and B: k = rate/([A][B]). Substituting the given values gives $k = 1.5 \times 10^{-2}/(0.2 \times 0.1) = 7.5 \times 10^{-2}$ L mol^{-1} s^{-1}. Therefore, the correct answer is (b).

28. **Which of the following statements is true about the Arrhenius equation?**
    A. It relates the rate constant of a reaction to the activation energy and temperature.
    B. It relates the equilibrium constant of a reaction to the standard Gibbs free energy change.
    C. It relates the solubility of a gas in a liquid to the partial pressure of the gas.
    D. It relates the rate of a reaction to the concentration of reactants.

Answer: A

The Arrhenius equation relates the rate constant (k) of a reaction to the activation energy (Ea), the temperature (T), and the frequency factor (A).

29. **What is the oxidation state of sulfur in H_2SO_4?**
    A. +2
    B. +4
    C. +6
    D. +8

Answer: C

The oxidation state of hydrogen is +1 and the oxidation state of oxygen is -2. Therefore, the sum of the oxidation states in H_2SO_4 must

30. Which of the following types of electromagnetic radiation has the highest energy?
   A. Radio waves
   B. Microwaves
   C. X-rays
   D. Visible light

Answer: C
Electromagnetic radiation is classified by its wavelength and frequency. Higher frequency radiation has higher energy. X-rays have a higher frequency and therefore higher energy than visible light, microwaves, and radio waves.

31. A sample of gas has a temperature of 273 K and a pressure of 1 atm. What is the volume of the gas in liters if there are 0.025 moles of gas present?
   A. 0.625 L
   B. 1.25 L
   C. 2.50 L
   D. 5.00 L

Answer: B

This problem can be solved using the Ideal Gas Law, which states that $PV = nRT$, where P is pressure, V is volume, n is the number of moles, R is the gas constant, and T is the temperature in Kelvin. Rearranging the equation to solve for V, we get $V = (nRT)/P$. Plugging in the given values, we get $V = (0.025\ mol)(0.0821\ L\cdot atm/K\cdot mol)(273\ K)/(1\ atm) = 1.25\ L$.

32. What is the hybridization of the central atom in SF4?
   A. sp
   B. sp^2
   C. sp^3
   D. sp^3d

Answer: D
The central atom in SF_4 is sulfur, which has six valence electrons. To form four covalent bonds with four fluorine atoms, sulfur must hybridize its orbitals. The hybridization of the central atom is determined by the number of electron pairs around it. In this case, there are four electron pairs, giving a hybridization of sp^3d.

33. What is the half-life of a first-order reaction with a rate constant of 0.0286 min⁻¹?
   A. 24.2 min
   B. 27.2 min

C. 30.2 min
D. 33.2 min

Answer: A
The half-life of a first-order reaction can be calculated using the equation t1/2 = ln(2)/k.
Substituting the given rate constant gives t1/2 = ln(2)/0.0286 = 24.2 min. Therefore, the
correct answer is (a).

34. Which of the following is NOT a characteristic of an ideal gas?
        A. Particles have zero volume
        B. Particles are in constant random motion
        C. Particles exert no attractive or repulsive forces on each other
        D. Particles have infinite energy

Answer: D
An ideal gas is a hypothetical gas composed of particles with zero volume, in constant
random motion, and with no attractive or repulsive forces between them.

35. How many unpaired electrons are present in the ground state of a nitrogen atom?
        A. 0
        B. 1
        C. 2
        D. 3

Answer: B
The electron configuration of a nitrogen atom is $1s^2\ 2s^2\ 2p^3$. The three unpaired electrons
are in the 2p subshell.

36. Which of the following reactions will have the highest activation energy?
        A. $NaCl\ (s) \rightarrow Na^+\ (aq) + Cl^-\ (aq)$
        B. $CH_4\ (g) + 2O_2\ (g) \rightarrow CO_2\ (g) + 2H_2O\ (g)$
        C. $H_2O\ (l) \rightarrow H_2O\ (g)$
        D. $2H_2\ (g) + O_2\ (g) \rightarrow 2H_2O\ (g)$

Answer: C
This reaction involves breaking the hydrogen bonds between water molecules, which
requires a significant amount of energy and therefore has the highest activation energy.

37. Which of the following is an example of a Bronsted-Lowry acid?
        A. NaOH
        B. HCl
        C. NH_3
        D. KOH

38. Which of the following statements is true about Gibbs free energy?

A. ΔG is always negative for spontaneous reactions.
B. ΔG is always positive for nonspontaneous reactions.
C. ΔG can be negative or positive depending on temperature and pressure.
D. ΔG is always zero at equilibrium.

Answer: C
Gibbs free energy (ΔG) depends on both the enthalpy (ΔH) and entropy (ΔS) of a system, as well as temperature and pressure, and can be positive or negative depending on these factors.

39. Which of the following is an example of a heterogeneous catalyst?

A. Platinum wire
B. Iron filings
C. Enzyme
D. Acid catalyst

Answer: A
Platinum wire is a heterogeneous catalyst because it is in a different phase (solid) from the reactants (gas or liquid) it is catalyzing.

40. Which of the following is a requirement for a molecule to exhibit aromaticity?

A. The molecule must have an odd number of pi electrons.
B. The molecule must have a cyclic structure.
C. The molecule must have a planar structure.
D. The molecule must have at least one double bond.

Answer: B
A molecule must have a cyclic structure that is planar and follows Hückel's rule (4n+2 pi electrons) to exhibit aromaticity.

41. Which of the following statements is true about hybrid orbitals?

A. They result from the mixing of s and p orbitals.
B. They are used to describe the shapes of molecules.
C. They are used to explain the properties of metals.
D. They are only found in the ground state of an atom.

Hybrid orbitals are formed by mixing atomic orbitals (usually s and p orbitals) in the valence shell of an atom to form new hybrid orbitals with different shapes and energies.

42. Which of the following is a characteristic of a first-order reaction?

      A. The rate is proportional to the square of the concentration of one of the reactants.
      B. The rate is independent of the concentration of the reactants.
      C. The rate is proportional to the product of the concentrations of the reactants.
      D. The rate is proportional to the concentration of one of the reactants.

Answer: D

In a first-order reaction, the rate of the reaction is directly proportional to the concentration of one of the reactants.

43. Which of the following statements is true about the solubility product constant, Ksp?

      A. It is a measure of the solubility of a solute in a solvent.
      B. It is the equilibrium constant for a precipitation reaction.
      C. It is independent of temperature.
      D. It is the product of the concentrations of the dissolved ions in a solution.

Answer: B

The solubility product constant, Ksp, is the equilibrium constant for a precipitation reaction between a sparingly soluble salt and water, and it describes the extent to which the salt dissolves in water.

44. Which of the following is an example of a nucleophile?

      A. H^+
      B. Na^+
      C. Br^-
      D. Cl_2

Answer:C

A nucleophile is an electron-rich species that is attracted to a positive or partially positive charge. Br^- has an extra electron and can donate it to an electron-deficient atom or molecule, making it a nucleophile.

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