Chemistry SL

IB SL — Answer Key

Q1.

Q2.

Q3.

Q4.

Q5.

Q6.

Q7.

Q8.

Q9.

Q10.

Q11.

Answer: H_2O is bent/V-shaped with a bond angle of approximately 104.5°.

Q12.

Answer: NH_3 is trigonal pyramidal with bond angles of approximately 107°.

Q13.

Answer: CCl_4 has polar C–Cl bonds but is a **non-polar molecule** because its tetrahedral symmetry causes the bond dipoles to cancel. It has no net dipole moment.

Q14.

Answer: HF has a higher boiling point than HCl because HF molecules form hydrogen bonds (H directly bonded to F), which are much stronger than the dipole–dipole forces between HCl molecules.

Q15.

Answer: Molecular polarity depends on both bond polarity and molecular geometry. Symmetric shapes (BF_3, CF_4) cancel dipoles; asymmetric shapes (NF_3, due to the lone pair) do not.

Q16.

Answer: HCl to HI trend is due to increasing London forces; HF is anomalous due to hydrogen bonding; $NaCl$ has a far higher melting point because ionic bonding in a lattice is much stronger than intermolecular forces.

Q17.

Answer: Diamond (4 covalent bonds, no free electrons) and ice (molecular, no mobile charges) are non-conductors. Graphite conducts because each carbon contributes one delocalised electron that is free to move along the layers.

Q18.

Q19.

Q20.

Q21.

Q22.

Q23.

Q24.

Q25.

Q26.

Q27.

Q28.

Answer:

The catalyst provides an alternative reaction pathway with a lower activation energy (80 kJ mol^{-1} instead of 120 kJ mol^{-1}). On the Maxwell-Boltzmann energy distribution diagram, the activation energy threshold shifts to the left. A significantly greater proportion of molecules now have kinetic energy greater than or equal to 80 kJ mol^{-1} compared to 120 kJ mol^{-1}. This means a greater fraction of collisions are effective, so the rate of reaction increases. The overall energy of the reactants and products, and therefore ΔH, is unchanged.

Q29.

Q30.

Q31.

Q32.

Q33.

Q34.

Q35.

Q36.

Q37.

Q38.

Answer: Higher concentration increases collision frequency; higher temperature increases the fraction of particles exceeding E_a; a catalyst lowers E_a via an alternative pathway, increasing the proportion of successful collisions.

Q39.

Answer: $K_c = 50$. Since K_c decreases with increasing temperature, the forward reaction is exothermic ($\Delta H < 0$).

Q40.

Answer: High pressure favours $\mathrm{NH_3}$ (fewer gas moles on right). 400-500 $^\circ\mathrm{C}$ is a compromise between yield (favoured by low T) and rate (favoured by high T). The catalyst speeds up attainment of equilibrium but does not change K_c or equilibrium position.

Q41.

Answer: As you move down Group 1 from Li to K, each element has an additional electron shell. The valence electron (the one lost in the reaction) is in a higher principal energy level ($n = 4$ for K vs. $n = 2$ for Li), which is further from the nucleus. Additionally, there are more inner electron shells between the valence electron and the nucleus in K, increasing the shielding effect. Both factors reduce the effective nuclear charge felt by the valence electron. Consequently, the first ionisation energy of K is lower than that of Li, meaning K loses its outer electron more easily and reacts more vigorously.

Q42.

Q43.

Answer: pH = 2

Q44.

Q45. C

Why: A conjugate acid-base pair consists of two species that differ by exactly one proton (H^+). NH_3 (base) accepts a proton to form NH_4^+ (conjugate acid). Option A is an acid and a base but not a conjugate pair (they don't differ by one H^+). Option B differs by 2 protons. Option D is two different acids.

Q46. C

Why: HNO_3 is a strong acid, so it fully ionizes: $[H^+] = 0.001 = 10^{-3}$. pH $= -\log(10^{-3}) = 3$.

Q47. C

Why: Ethanoic acid is a weak acid. At the equivalence point, the solution contains sodium ethanoate (CH_3COONa). The ethanoate ion (CH_3COO^-) is the conjugate base of a weak acid, so it hydrolyses slightly to produce OH^-, making the solution basic (pH > 7).

Q48. C

Why: The definition of "strong" in chemistry refers to the degree of ionization, not concentration. A strong acid completely dissociates into ions ($\rightarrow$); a weak acid establishes an equilibrium ($\rightleftharpoons$). Option D is only true at the same concentration.

Q49. C

Why: At the equivalence point of a weak acid–strong base titration, the solution contains sodium ethanoate ($CH_3COO^-Na^+$). The ethanoate ion is the conjugate base of a weak acid and partially hydrolyses: $CH_3COO^- + H_2O \rightleftharpoons CH_3COOH + OH^-$, producing excess OH^- and giving pH > 7. pH = 7 only at the equivalence point of strong acid + strong base.

Q50. B

Why: HCO_3^- is amphiprotic: it can donate a proton ($HCO_3^- \rightarrow CO_3^{2-} + H^+$, acting as an acid) or accept a proton ($HCO_3^- + H^+ \rightarrow H_2CO_3$, acting as a base). NH_4^+ (D) can only donate a proton — it is a weak acid, not amphiprotic.

Q51. B

Why: When a small amount of acid (H^+) is added, the conjugate base (CH_3COO^-) absorbs it, forming the weak acid CH_3COOH. This keeps $[H^+]$ nearly constant. Option A describes how the buffer responds to added base (OH^-), not added acid.

Q52.

Answer: Sulfur has an oxidation number of $+6$ in H_2SO_4.

Q53.

Answer: Chromium has an oxidation number of $+6$ in $Cr_2O_7^{2-}$.

Q54.

Q55.

Q56.

Q57.

Q58.

Answer: Zn is the anode. Cell EMF = $+1.10$ V. The positive value confirms this reaction is spontaneous.

Q59. B

Why: Carbon in CO has oxidation number $+2$; in CO_2 it is $+4$ — carbon has been oxidized (lost electrons). The substance that is oxidized is the reducing agent. Iron in Fe_2O_3 goes from $+3$ to 0 — it is reduced, making Fe_2O_3 the oxidizing agent.

Q60. C

Why: Oxygen is -2 each ($-2 \times 3 = -6$). The sum must equal the ion charge (-1): $x + (-6) = -1$, so $x = +5$.

Q61. D

Why: Zinc is more reactive than silver. Zn displaces Ag: $Zn + 2Ag^+ \rightarrow Zn^{2+} + 2Ag$. Silver metal (grey) deposits on the zinc strip. The colourless Zn^{2+} ions replace Ag^+ in solution.

Q62. B

Why: AN OX RED CAT — oxidation occurs at the anode. Reduction occurs at the cathode. The salt bridge allows ion flow; the wire carries electrons.

Q63. C

Why: In H_2SO_4: each H is $+1$ (total $+2$), each O is -2 (total -8). Sum must equal 0 (neutral compound): $+2 + x + (-8) = 0$, so $x = +6$. This is the maximum oxidation state of sulfur and is why H_2SO_4 is a strong oxidizing agent in concentrated form.

Q64. B

Why: Zinc is more reactive (higher up in the activity series) and is oxidized: $Zn \rightarrow Zn^{2+} + 2e^-$ (anode). Copper ions are reduced: $Cu^{2+} + 2e^- \rightarrow Cu$ (cathode). The salt bridge transfers **ions** (not electrons) to maintain electrical neutrality. The cell produces a positive EMF because zinc is the stronger reducing agent.

Q65. A

Why: In $Fe(OH)_3$, iron is $+3$ (increased from 0 — oxidized). In O_2, oxygen is 0; in $Fe(OH)_3$ and H_2O, oxygen is -2 (decreased — reduced). This is a redox reaction: Fe is the reducing agent, O_2 is the oxidizing agent.

Q66. C

Why: $CH_3CH_2CH_2OH$ is propan-1-ol, an alcohol. Members of the same homologous series share the same functional group (-OH). CH_3OH (methanol) is also an alcohol. Option A is an ether, B is an aldehyde, and D is a carboxylic acid.

Q67. C

Why: Ethanal (CH_3CHO, an aldehyde) and propanone (CH_3COCH_3, a ketone) share the same general formula but have different functional groups. They are functional group isomers. They are NOT structural isomers (different molecular formulas: C_2H_4O vs C_3H_6O) and NOT homologues (different functional groups).

Q68. C

Why: The longest continuous chain has 4 carbons (butane). Numbering from the end closest to the branch gives a methyl group on carbon 2. The name is 2-methylbutane, not 3-methylbutane (always use the lowest locant).

Q69. B

Why: The longest chain with -OH has 4 carbons (butane). The -OH group is on carbon 2 (numbering from the end nearest to -OH). The correct IUPAC name is butan-2-ol. Option C uses incorrect numbering; option D uses an older naming convention.

Q70.

Q71. B

Why: C_4H_{10} (an alkane) has exactly 2 structural isomers: butane ($CH_3CH_2CH_2CH_3$, straight chain) and 2-methylpropane ($(CH_3)_3CH$, branched). There are no other ways to arrange 4 carbons and 10 hydrogens.

Q72. D

Why: The classification primary/secondary/tertiary refers to how many other carbon atoms are bonded to the carbon carrying the functional group. In 2-methylpropan-2-ol, the carbon bearing -OH is bonded to three methyl groups, making it tertiary. This is critical because tertiary alcohols cannot be oxidised.

Q73. C

Why: Incomplete combustion occurs with limited oxygen. Carbon forms CO (carbon monoxide) and/or C (soot/carbon) instead of CO_2. Water is still produced. Hydrogen gas (H_2) is NOT a product of combustion.

Q74. C

Why: Balancing $C_4H_{10} + O_2$: 4 carbons need 4 CO_2; 10 hydrogens need 5 H_2O (requiring 8 + 5 = 13 oxygen atoms, so 6.5 O_2). Multiply through by 2 to get whole numbers: $2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$.

Q75. C

Why: Bromine water decolourises when Br_2 adds across a C=C double bond (addition reaction). This is the standard test for unsaturation. Alkanes are saturated and would not decolourise bromine water.

Q76. B

Why: This is a hydration reaction (addition of water across C=C). The water adds across the double bond to form an alcohol. In propene, the -OH preferentially bonds to the more substituted carbon (carbon 2), giving propan-2-ol as the major product (Markovnikov's rule).

Q77. A

Why: But-2-ene ($CH_3CH{=}CHCH_3$) is a symmetrical internal alkene. Adding HBr across the double bond gives only one product: 2-bromobutane ($CH_3CHBrCH_2CH_3$). In contrast, but-1-ene (a terminal, asymmetric alkene) would give two possible products.

Q78.

Q79. C

Why: Primary and secondary alcohols are oxidised by acidified $K_2Cr_2O_7$, causing the solution to change from orange to green. If the solution stays orange, no oxidation has occurred. This is the characteristic result for a tertiary alcohol, which has no hydrogen on the carbon bearing -OH.

Q80. C

Why: To obtain the carboxylic acid, you need excess oxidising agent and reflux conditions. Reflux keeps the intermediate aldehyde in the flask so it is further oxidised. Distillation would remove the aldehyde before further oxidation can occur, stopping at ethanal.

Q81. C

Why: Propan-1-ol is a primary alcohol. With limited oxidising agent and distillation, it is oxidised to propanal (an aldehyde). Tollens' reagent (ammoniacal silver nitrate) reacts with aldehydes: Ag^+ ions are reduced to metallic silver, forming a silver mirror. Ketones do not give this result.

Q82.

Q83. B

Why: Butanone is a ketone (C=O in the middle of the chain). Reduction with $NaBH_4$ converts C=O to C-OH, giving a secondary alcohol. The -OH ends up on carbon 2 (the same carbon that had the C=O), producing butan-2-ol. Ketones always reduce to secondary alcohols.

Q84. C

Why: Reduction means adding hydrogen (or [H]). The C=O double bond in the aldehyde gains hydrogen to become C-OH. The reagent is $NaBH_4$ (sodium tetrahydridoborate). Options A and D describe oxidation, not reduction. Option B incorrectly uses [O].

Q85.

Q86.

Q87. B

Why: The ester name is built as [alcohol part]-yl [acid part]-anoate. The alcohol is methanol (gives "methyl"), and the acid is ethanoic acid (gives "ethanoate"). So the product is methyl ethanoate (CH_3COOCH_3). A common IB trap is reversing the two parts.

Q88. C

Why: Esterification is a condensation reaction because two molecules (carboxylic acid + alcohol) join together with the loss of a small molecule — water (H_2O). It is NOT addition (no C=C involved) and NOT substitution (no atom is replaced by another).

Q89.

Q90.

Q91.

Q92. B

Why: 2-Bromo-2-methylpropane is a tertiary halogenoalkane (the carbon bearing Br is bonded to three other carbons). Tertiary halogenoalkanes react by SN1: the halogen leaves first to form a stable tertiary carbocation, then the nucleophile (OH^-) attacks. Primary halogenoalkanes react by SN2.

Q93. C

Why: SN2 is bimolecular — the rate-determining step involves both the substrate (halogenoalkane) and the nucleophile (OH^-) in a single concerted step. In contrast, SN1 is unimolecular — its rate depends only on the concentration of the halogenoalkane, because the slow step is the loss of the halide ion.

Q94. C

Why: Initiation is the first step where UV light causes homolytic fission of the Cl-Cl bond, producing two chlorine free radicals. Option B is a propagation step. Option D is a termination step. The C-H bond in methane is too strong to break by UV light alone.

Q95. D

Why: Termination occurs when two free radicals combine, removing radicals from the system and ending the chain reaction. $CH_3\cdot + CH_3\cdot \rightarrow C_2H_6$ combines two radicals. This also explains why ethane (C_2H_6) can be detected as a minor by-product.

Q96. C

Why: In addition polymerization, the C=C double bond opens up. The repeating unit is drawn by converting C=C to C-C and showing the bonds extending outside the brackets. The substituent (Cl) stays on the same carbon. This polymer is PVC (poly(chloroethene)).

Q97. C

Why: The key difference is that condensation polymerization releases a small molecule (usually water) with each bond formed, while addition polymerization produces no by-product. Addition polymers come from alkene monomers (with C=C). Condensation polymers come from bifunctional monomers (e.g. diols + dicarboxylic acids).

Q98. C

Why: The -OH group in ethanol allows hydrogen bonding between molecules (O-H$\cdots$O). Hydrogen bonds are much stronger than London dispersion forces (the only intermolecular force in ethane). More energy is needed to separate ethanol molecules, so the boiling point is higher. Covalent bond strength is irrelevant to boiling point — it is intermolecular forces that matter.

Q99.

Answer: The compound contains -OH and -COOH groups, is named 3-hydroxypentanoic acid, and can be distinguished from pentane by its acidic reaction with indicators or $NaHCO_3$.

Q100.

Answer: 1-bromobutane (primary) undergoes S_N2 due to low steric hindrance; 2-bromo-2-methylpropane (tertiary) undergoes S_N1 via a stable tertiary carbocation intermediate.

Q101.

Answer: Ethanol combusts to CO_2 and H_2O; is oxidised to ethanal (aldehyde, distillation) then ethanoic acid (carboxylic acid, reflux); and reacts with ethanoic acid to form ethyl ethanoate (esterification).

Q102.

Q103.

Q104.

Q105.

Q106.