

Name: _____

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IB Chemistry — Practice Exam

Instructions: A calculator is permitted. Answer all questions in the spaces provided and show your working: method marks are awarded even when the final answer is wrong. Relative atomic masses and other data needed are given in the questions.

Time Limit: 60 minutes

Multiple Choice (15 questions)

- [1 point] 1. A compound contains 52.2% carbon, 13.0% hydrogen and 34.8% oxygen by mass. Using relative atomic masses C = 12.0, H = 1.0 and O = 16.0, what is its empirical formula?
- A. CH₃O
 - B. C₂H₆O
 - C. C₂H₄O
 - D. C₃H₈O
- [1 point] 2. Calcium carbonate decomposes on heating: $\text{CaCO}_3(\text{s}) \rightarrow \text{CaO}(\text{s}) + \text{CO}_2(\text{g})$. What volume of carbon dioxide, measured at STP (273 K and 100 kPa, molar volume 22.7 dm³ mol⁻¹), is produced when 10.0 g of calcium carbonate ($M = 100.1 \text{ g mol}^{-1}$) decomposes completely?
- A. 1.14 dm³
 - B. 2.27 dm³
 - C. 4.54 dm³
 - D. 22.7 dm³
- [1 point] 3. Aluminium reacts with chlorine according to $2\text{Al} + 3\text{Cl}_2 \rightarrow 2\text{AlCl}_3$. 0.40 mol of aluminium is mixed with 0.45 mol of chlorine. What is the maximum amount of aluminium chloride that can form?
- A. 0.30 mol
 - B. 0.40 mol
 - C. 0.45 mol
 - D. 0.60 mol

[1 point] 4. Iron is element 26. What is the electron configuration of the Fe^{3+} ion?

- A. $[\text{Ar}] 3d^5$
- B. $[\text{Ar}] 3d^3 4s^2$
- C. $[\text{Ar}] 3d^6 4s^2$
- D. $[\text{Ar}] 3d^4 4s^1$

[1 point] 5. Which pair of species both have a bent (V-shaped) molecular geometry?

- A. CO_2 and SO_2
- B. H_2O and NO_2^-
- C. BeCl_2 and H_2S
- D. HCN and OF_2

[1 point] 6. Which compound has the highest boiling point?

- A. $\text{CH}_3\text{CH}_2\text{CH}_3$ (propane)
- B. CH_3OCH_3 (methoxymethane)
- C. $\text{CH}_3\text{CH}_2\text{OH}$ (ethanol)
- D. CH_3CHO (ethanal)

[1 point] 7. The ions O^{2-} , F^- , Na^+ and Mg^{2+} all have the electron configuration $1s^2 2s^2 2p^6$. Which ion has the largest radius?

- A. O^{2-}
- B. F^-
- C. Na^+
- D. Mg^{2+}

[1 point] 8. What is the IUPAC name of the compound $\text{CH}_3\text{CH}(\text{CH}_3)\text{CH}_2\text{CHO}$?

- A. 2-methylbutanal
- B. 3-methylbutanal
- C. 2-methylbutan-1-ol
- D. 3-methylbutan-2-one

[1 point] 9. 0.46 g of ethanol ($M = 46 \text{ g mol}^{-1}$) is burned completely and the energy released heats 50.0 g of water by 10.0 K. The specific heat capacity of water is $4.18 \text{ J g}^{-1} \text{ K}^{-1}$. Assuming no energy losses, what value does this experiment give for the enthalpy of combustion of ethanol?

- A. $-2.09 \text{ kJ mol}^{-1}$
- B. $-20.9 \text{ kJ mol}^{-1}$
- C. -209 kJ mol^{-1}
- D. $+209 \text{ kJ mol}^{-1}$

- [1 point] 10. A reaction has $\Delta H = +50 \text{ kJ mol}^{-1}$ and $\Delta S = +100 \text{ J K}^{-1} \text{ mol}^{-1}$, both independent of temperature. Under which conditions is the reaction spontaneous?
- A. At all temperatures
 - B. Only at temperatures below 500 K
 - C. Only at temperatures above 500 K
 - D. At no temperature
- [1 point] 11. Which change alters the shape of the Maxwell–Boltzmann distribution of molecular energies in a gaseous reaction mixture?
- A. Increasing the concentration of a reactant
 - B. Adding a catalyst
 - C. Increasing the temperature
 - D. Increasing the surface area of a solid reactant
- [1 point] 12. At a certain temperature the equilibrium concentrations in the system $\text{H}_2(\text{g}) + \text{I}_2(\text{g}) \rightleftharpoons 2\text{HI}(\text{g})$ are $[\text{H}_2] = 0.20$, $[\text{I}_2] = 0.20$ and $[\text{HI}] = 1.6$, all in mol dm^{-3} . What is the value of the equilibrium constant K ?
- A. 0.016
 - B. 8.0
 - C. 40
 - D. 64
- [1 point] 13. What is the pH of a $0.050 \text{ mol dm}^{-3}$ solution of sulfuric acid, assuming it is completely dissociated into H^+ and SO_4^{2-} ions?
- A. 0.70
 - B. 1.0
 - C. 1.3
 - D. 2.0
- [1 point] 14. Which change represents an oxidation?
- A. $\text{MnO}_4^- \rightarrow \text{Mn}^{2+}$
 - B. $\text{Cr}_2\text{O}_7^{2-} \rightarrow \text{Cr}^{3+}$
 - C. $\text{SO}_2 \rightarrow \text{SO}_4^{2-}$
 - D. $\text{NO}_3^- \rightarrow \text{NO}_2$
- [1 point] 15. A voltaic cell is made from a zinc electrode in zinc sulfate solution and a copper electrode in copper(II) sulfate solution, connected by a salt bridge. Zinc is the more reactive metal. Which statement is correct?
- A. The zinc electrode is the cathode and is the site of reduction
 - B. Electrons flow from the zinc electrode to the copper electrode through the external circuit
 - C. Cu^{2+} ions are oxidised at the copper electrode
 - D. Positive ions from the salt bridge move into the zinc half-cell

Calculations (2 questions)

[10 points] 16. Ethanol, $\text{C}_2\text{H}_5\text{OH}$, is used as a fuel. Standard enthalpies of formation, in kJ mol^{-1} : $\text{C}_2\text{H}_5\text{OH(l)}$ -278 ; $\text{CO}_2\text{(g)}$ -394 ; $\text{H}_2\text{O(l)}$ -286 . Average bond enthalpies, in kJ mol^{-1} : C-H 414 ; C-C 346 ; C-O 358 ; O-H 463 ; O=O 498 ; C=O (in CO_2) 804 .

[1 point] (a) Write the equation, including state symbols, for the complete combustion of ethanol.

[2 points] (b) Calculate the standard enthalpy of combustion of ethanol using the enthalpies of formation.

[3 points] (c) Calculate the enthalpy of combustion of ethanol using the average bond enthalpies.

[1 point] (d) Suggest why the values obtained in (b) and (c) differ.

[1 point] (e) Predict, giving a reason, the sign of the entropy change ΔS for the reaction in (a).

[2 points] (f) The standard entropy change for the reaction is $-139 \text{ J K}^{-1} \text{ mol}^{-1}$. Using your answer to (b), calculate ΔG at 298 K and deduce whether the reaction is spontaneous.

[10 points] 17. Ethanoic acid, CH_3COOH , is a weak acid. A student titrates 25.0 cm^3 of $0.100 \text{ mol dm}^{-3}$ ethanoic acid with $0.0500 \text{ mol dm}^{-3}$ sodium hydroxide solution. In a separate experiment, magnesium ribbon is added to a sample of the acid.

[2 points] (a) Write an equation for the dissociation of ethanoic acid in water and identify one conjugate acid–base pair.

[2 points] (b) Distinguish between a strong acid and a weak acid, and state how the pH of $0.100 \text{ mol dm}^{-3}$ ethanoic acid compares with that of $0.100 \text{ mol dm}^{-3}$ hydrochloric acid.

[2 points] (c) Calculate the volume of sodium hydroxide solution needed to reach the equivalence point of the titration.

[2 points] (d) Sodium ethanoate is dissolved in a solution of ethanoic acid. Predict, using Le Châtelier's principle, the effect on the pH of the solution.

- [2 points]** (e) Magnesium reacts with the acid: $\text{Mg} + 2\text{CH}_3\text{COOH} \rightarrow (\text{CH}_3\text{COO})_2\text{Mg} + \text{H}_2$. Deduce the changes in oxidation state that occur and identify the oxidising agent.