AP Chemistry

Worked Solutions · 解题范例

AP Chemistry free-response is scored on a claim supported by cited evidence and explicit reasoning, so a correct number with no justification routinely earns a fraction of the marks. Each solution below shows the working AND the sentence the rubric is looking for. 评分要求“结论 + 证据 + 推理”, 本册两者都给出。

Stoichiometry and gases

A 2.50 g sample of an unknown hydrocarbon burns completely to give 7.70 g of CO_2 and 3.15 g of H_2O. Determine its empirical formula.

CH_2 – the empirical formula.

All the carbon in the CO_2 came from the sample: $n(CO_2) = 7.70/44.01 = 0.175$ mol, so 0.175 mol C. All the hydrogen came from the H_2O, and each water carries two hydrogens: $n(H_2O) = 3.15/18.02 = 0.175$ mol, so 0.350 mol H. Divide by the smaller: C 1.00, H 2.00, giving CH_2. Check the mass: 0.175(12.01) + 0.350(1.008) = 2.10 + 0.35 = 2.45 g, close to 2.50 within rounding, which confirms the hydrocarbon contains no oxygen.

A 0.500 L vessel at 300 K contains 0.0400 mol of nitrogen and 0.0200 mol of oxygen. Find the partial pressure of each gas and the total pressure.

N_2 1.97 atm, O_2 0.985 atm, total 2.96 atm.

Each gas exerts the pressure it would exert alone: $P = nRT/V$. For nitrogen, (0.0400)(0.0821)(300)/0.500 = 1.97 atm; oxygen has half the moles so half the pressure, 0.985 atm. Dalton's law gives the total as the sum, 2.96 atm. The reasoning to state is that in an ideal gas the particles do not interact, so each contributes independently of the identity of the others.

Equilibrium and acids

A 0.100 M solution of a weak acid has pH 2.87. Calculate its Ka.

$Ka = 1.8 \times 10^{-5}$.

From the pH, $[H^+] = 10^{-2\ .\ 87} = 1.35 \times 10^{-3}$ M. In an ICE table, the acid loses that much and the conjugate base gains it, so at equilibrium [HA] = 0.100 − 0.00135 = 0.0987 M. $Ka = (1.35e{-}3)^2/0.0987 = 1.8 \times 10^{-5}$. State the approximation you used and check it: the ionisation is 1.35 per cent of the initial concentration, well under 5 per cent, so treating [HA] as 0.100 would also have been acceptable. Saying that the check was made is itself scored.

50.0 mL of 0.200 M CH_3COOH ($Ka = 1.8 \times 10^{-5}$) is titrated with 0.200 M NaOH. Find the pH after 25.0 mL of base has been added.

pH = 4.74.

25.0 mL is exactly half the volume needed to neutralise, so this is the half-equivalence point: half the acid has been converted to its conjugate base, making $[HA] = [A^-]$. In the Henderson-Hasselbalch relationship the log term is then log(1) = 0, so pH = pKa = −log(1.8e−5) = 4.74. Recognising the half-equivalence point removes the entire calculation, which is why the exam sets the volumes this way.

For $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$, ΔH is negative. Predict and justify the effect on the yield of ammonia of (a) raising the temperature and (b) raising the pressure.

(a) The yield falls. (b) The yield rises.

Raising the temperature adds heat, and for an exothermic reaction heat is effectively a product, so the system shifts towards the reactants to consume the added energy – reducing the yield and lowering K. Raising the pressure reduces the volume available; the system shifts towards the side with fewer moles of gas, and there are four moles on the left against two on the right, so it shifts right and the yield rises. Note that pressure changes the position but NOT the value of K, while temperature changes both – that distinction is examined directly.

Thermodynamics and kinetics

A reaction has $\Delta H = +58$ kJ/mol and $\Delta S = +176$ J/(mol · K). Determine the temperature above which it becomes thermodynamically favourable.

Above about 330 K.

$\Delta G = \Delta H - T\Delta S$, and the reaction is favourable when ΔG is negative. Convert the entropy to kilojoules first: 0.176 kJ/(mol · K). Setting $\Delta G = 0$ gives $T = \Delta H/\Delta S = 58/0.176 = 330$ K. Above that temperature the $T\Delta S$ term exceeds ΔH and ΔG turns negative. The unit conversion is where most of the lost marks are; the reasoning is one sentence.

For a reaction A + B → C, doubling [A] doubles the rate; doubling [B] leaves the rate unchanged. Write the rate law and give the units of k.

Rate = k[A]; k has units of s^{-1}.

The order in A is one because the rate scales in proportion, and the order in B is zero because the rate does not respond at all. So rate = $k[A]^1[B]^0 = k[A]$. For the units, rate is M s^{-1} and [A] is M, so k must be s^{-1}. State explicitly that orders come from experiment, not from the coefficients in the equation – a rate law read off the stoichiometry is a standard trap and this question is set to catch it.

A galvanic cell is built from Zn^{2+}/Zn ($E° = -0.76$ V) and Cu^{2+}/Cu ($E° = +0.34$ V). Identify the anode and calculate the standard cell potential.

Zinc is the anode; E°cell = +1.10 V.

The more negative electrode potential is the one that is oxidised, so zinc is the anode and copper the cathode. E°cell = E°(cathode) − E°(anode) = 0.34 − (−0.76) = +1.10 V. The positive value confirms the cell is galvanic and that ΔG is negative – say so, since the link between a positive cell potential and a spontaneous reaction is usually a separate scoring point.