

PART II

A5.5 Standard Reduction Potentials at 25°C (298 K) for Many Common Half-Reactions

Half-Reaction	e° (V)	Half-Reaction	e° (V)
$F_2 + 2e^- \rightarrow 2F^-$	2.87	$Cu^+ + e^- \rightarrow Cu$	0.52
$Ag^{2+} + e^- \rightarrow Ag^+$	1.99	$O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$	0.40
$Co^{3+} + e^- \rightarrow Co^{2+}$	1.82	$Cu^{2+} + 2e^- \rightarrow Cu$	0.34
$H_2O_2 + 2H^+ + 2e^- \rightarrow 2H_2O$	1.78	$Hg_2Cl_2 + 2e^- \rightarrow 2Hg + 2Cl^-$	0.34
$Ce^{4+} + e^- \rightarrow Ce^{3+}$	1.70	$AgCl + e^- \rightarrow Ag + Cl^-$	0.22
$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightarrow PbSO_4 + 2H_2O$	1.69	$SO_4^{2-} + 4H^+ + 2e^- \rightarrow H_2SO_3 + H_2O$	0.20
$MnO_4^- + 4H^+ + 3e^- \rightarrow MnO_2 + 2H_2O$	1.68	$Cu^{2+} + e^- \rightarrow Cu^+$	0.16
$2e^- + 2H^+ + IO_4^- \rightarrow IO_3^- + H_2O$	1.60	$2H^+ + 2e^- \rightarrow H_2$	0.00
$MnO_4^- + 8H^+ + 5e^- \rightarrow Mn^{2+} + 4H_2O$	1.51	$Fe^{3+} + 3e^- \rightarrow Fe$	-0.036
$Au^{3+} + 3e^- \rightarrow Au$	1.50	$Pb^{2+} + 2e^- \rightarrow Pb$	-0.13
$PbO_2 + 4H^+ + 2e^- \rightarrow Pb^{2+} + 2H_2O$	1.46	$Sn^{2+} + 2e^- \rightarrow Sn$	-0.14
$Cl_2 + 2e^- \rightarrow 2Cl^-$	1.36	$Ni^{2+} + 2e^- \rightarrow Ni$	-0.23
$Cr_2O_7^{2-} + 14H^+ + 6e^- \rightarrow 2Cr^{3+} + 7H_2O$	1.33	$PbSO_4 + 2e^- \rightarrow Pb + SO_4^{2-}$	-0.35
$O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$	1.23	$Cd^{2+} + 2e^- \rightarrow Cd$	-0.40
$MnO_2 + 4H^+ + 2e^- \rightarrow Mn^{2+} + 2H_2O$	1.21	$Fe^{2+} + 2e^- \rightarrow Fe$	-0.44
$IO_3^- + 6H^+ + 5e^- \rightarrow \frac{1}{2} I_2 + 3H_2O$	1.20	$Cr^{3+} + e^- \rightarrow Cr^{2+}$	-0.50
$Br_2 + 2e^- \rightarrow 2Br^-$	1.09	$Cr^{3+} + 3e^- \rightarrow Cr$	-0.73
$VO_2^+ + 2H^+ + e^- \rightarrow VO^{2+} + H_2O$	1.00	$Zn^{2+} + 2e^- \rightarrow Zn$	-0.76
$AuCl_4^- + 3e^- \rightarrow Au + 4Cl^-$	0.99	$2H_2O + 2e^- \rightarrow H_2 + 2OH^-$	-0.83
$NO_3^- + 4H^+ + 3e^- \rightarrow NO + 2H_2O$	0.96	$Mn^{2+} + 2e^- \rightarrow Mn$	-1.18
$ClO_2 + e^- \rightarrow ClO_2^-$	0.954	$Al^{3+} + 3e^- \rightarrow Al$	-1.66
$2Hg_2^{2+} + 2e^- \rightarrow Hg_2^{2+}$	0.91	$H_2 + 2e^- \rightarrow 2H^-$	-2.23
$Ag^+ + e^- \rightarrow Ag$	0.80	$Mg^{2+} + 2e^- \rightarrow Mg$	-2.37
$Hg_2^{2+} + 2e^- \rightarrow 2Hg$	0.80	$La^{3+} + 3e^- \rightarrow La$	-2.37
$Fe^{3+} + e^- \rightarrow Fe^{2+}$	0.77	$Na^+ + e^- \rightarrow Na$	-2.71
$O_2 + 2H^+ + 2e^- \rightarrow H_2O_2$	0.68	$Ca^{2+} + 2e^- \rightarrow Ca$	-2.76
$MnO_4^- + e^- \rightarrow MnO_4^{2-}$	0.56	$Ba^{2+} + 2e^- \rightarrow Ba$	-2.90
$I_2 + 2e^- \rightarrow 2I^-$	0.54	$K^+ + e^- \rightarrow K$	-2.92
		$Li^+ + e^- \rightarrow Li$	-3.05

Advanced Placement Chemistry Equations and Constants

ATOMIC STRUCTURE

$$E = h\nu$$

$$\lambda = \frac{h}{m\nu}$$

$$E_n = \frac{-2.178 \times 10^{-18}}{n^2} \text{ joule}$$

$$c = \lambda\nu$$

$$p = m\nu$$

EQUILIBRIUM

$$K_a = \frac{[H^+][A^-]}{[HA]}$$

$$E^\circ =$$

$$K_w = [OH^-][H^+] = 1.0 \times 10^{-14} \text{ at } 25^\circ\text{C}$$

$$= K_a \times K_b$$

$$\text{pH} = -\log[H^+], \text{pOH} = -\log[OH^-]$$

$$14 = \text{pH} + \text{pOH}$$

$$\text{pH} = \text{p}K_a + \log \frac{[A^-]}{[HA]}$$

$$\text{pOH} = \text{p}K_b + \log \frac{[HB^+]}{[B]}$$

$$\text{p}K_a = -K_a, \text{p}K_b = -\log K_b$$

$$K_p = K_c(RT)^{\Delta n}$$

where Δn = moles product gas - moles reactant gas

THERMOCHEMISTRY/KINETICS

$$\Delta S^\circ = \sum S^\circ \text{ products} - \sum S^\circ \text{ reactants}$$

$$\Delta H^\circ = \sum \Delta H_f^\circ \text{ products} - \sum \Delta H_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \sum \Delta G_f^\circ \text{ products} - \sum \Delta G_f^\circ \text{ reactants}$$

$$\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ$$

$$= -RT \ln K = -2.303RT \log K$$

$$= -n \mathfrak{F} E^\circ$$

$$\Delta G = \Delta G^\circ + RT \ln Q = \Delta G^\circ + 2.303RT \log Q$$

$$q = mc\Delta T$$

$$C_p = \frac{\Delta H}{\Delta T}$$

$$\ln[A]_t - \ln[A]_0 = -kt$$

$$\frac{1}{[A]_t} - \frac{1}{[A]_0} = kt$$

$$\ln k = \frac{-E_a}{R} \left(\frac{1}{T} \right) + \ln A$$

$$E = \text{energy} \quad \nu = \text{frequency}$$

$$\lambda = \text{wavelength} \quad p = \text{momentum}$$

$$\nu = \text{velocity} \quad n = \text{principal quantum number}$$

$$m = \text{mass}$$

$$\text{Speed of light, } c = 3.0 \times 10^8 \text{ ms}^{-1}$$

$$\text{Planck's constant, } h = 6.63 \times 10^{-34} \text{ Js}$$

$$\text{Boltzmann's constant, } k = 1.38 \times 10^{-23} \text{ J K}^{-1}$$

$$\text{Avogadro's number} = 6.022 \times 10^{23} \text{ mol}^{-1}$$

$$\text{Electron charge, } e = -1.602 \times 10^{-19} \text{ coulomb}$$

$$1 \text{ electron volt per atom} = 96.5 \text{ kJ mol}^{-1}$$

EQUILIBRIUM CONSTANTS

K_a (weak acid)

K_b (weak base)

K_w (water)

K_p (gas pressure)

K_c (molar concentrations)

S° = standard entropy

H° = standard enthalpy

G° = standard free energy

E° = standard reduction potential

T = temperature

n = moles

m = mass

q = heat

c = specific heat capacity

C_p = molar heat capacity at constant pressure

E_a = activation energy

k = rate constant

A = frequency factor

Faraday's constant, $\mathfrak{F} = 96,500$ per mole of electrons

Gas constant, $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$

$$= 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$$

$$= 8.31 \text{ volt coulomb mol}^{-1} \text{ K}^{-1}$$

GASES, LIQUIDS, AND SOLUTIONS

$$PV = nRT$$

$$\left(P + \frac{n^2 a}{V^2} \right) (V - nb) = nRT$$

$$P_A = P_{\text{total}} \times X_A, \text{ where } X_A = \frac{\text{moles } A}{\text{total moles}}$$

$$P_{\text{total}} = P_A + P_B + P_C + \dots$$

$$n = \frac{m}{M}$$

$$^\circ\text{K} = ^\circ\text{C} + 273$$

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$D = \frac{m}{V}$$

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$$u_{rms} = \sqrt{\frac{3kT}{m}} = \sqrt{\frac{3RT}{M}}$$

$$KE \text{ per molecule} = \frac{1}{2}mv^2$$

$$KE \text{ per mole} = \frac{3}{2}RT$$

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}$$

molarity, M = moles solute per liter solution

molality = moles solute per kilogram solvent

$$\Delta T_f = iK_f \times \text{molality}$$

$$\Delta T_b = iK_b \times \text{molality}$$

$$\pi = MRT$$

$$A = abc$$

OXIDATION-REDUCTION; ELECTROCHEMISTRY

$$Q = \frac{[C]^c[D]^d}{[A]^a[B]^b}, \text{ where } aA + bB \rightarrow cC + dD$$

$$I = \frac{q}{t}$$

$$E_{\text{cell}} = E_{\text{cell}}^{\circ} - \frac{RT}{n\mathcal{F}} \ln Q = E_{\text{cell}}^{\circ} - \frac{0.0592}{n} \log Q @ 25^{\circ}\text{C}$$

$$\log K = \frac{nE^{\circ}}{0.0592}$$

P = pressure

V = volume

T = temperature

n = number of moles

D = density

m = mass

v = velocity

u_{rms} = root-mean-square speed

KE = kinetic energy

r = rate of effusion

M = molar mass

π = osmotic pressure

i = van't Hoff factor

K_f = molal freezing-point depression constant

K_b = molal boiling-point elevation constant

A = absorbance

a = molar absorptivity

b = path length

c = concentration

Q = reaction quotient

I = current (amperes)

q = charge (coulombs)

t = time (seconds)

E° = standard reduction potential

K = equilibrium constant

Gas constant, $R = 8.31 \text{ J mol}^{-1} \text{ K}^{-1}$

$= 0.0821 \text{ L atm mol}^{-1} \text{ K}^{-1}$

$= 8.31 \text{ volt coulomb mol}^{-1} \text{ K}^{-1}$

Boltzmann's constant, $k = 1.38 \times 10^{-23} \text{ J K}^{-1}$

K_f for $\text{H}_2\text{O} = 1.86 \text{ K kg mol}^{-1}$

K_b for $\text{H}_2\text{O} = 0.512 \text{ K kg mol}^{-1}$

$1 \text{ atm} = 760 \text{ mm Hg}$

$= 760 \text{ torr}$

STP = 0.000°C and 1.000 atm

Faraday's constant, $\mathcal{F} = 96,500 \text{ coulombs per mole of electrons}$

Section II: Free-Response Questions

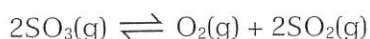
Time: 90 minutes

Number of Questions: 6

Section II of the AP Chemistry Examination counts for 55% of the total test grade and involves several parts. In the actual exam, there will be a choice of questions, but here you should do all questions because the choices are omitted. Calculators may be used on the first two questions only. A Periodic Table and Equation Tables are provided elsewhere in this study guide and may be used.

Part A: Time—40 minutes

1. Equilibrium (worth 20% of this part of the test)



A 3.21 g sample of sulfur trioxide is placed in a 2.25-L cylinder and allowed to reach equilibrium at a constant temperature of 500.K, as shown in the above equation. Analysis shows 1.23×10^{-2} mol of sulfur dioxide at equilibrium.

- Write the equilibrium constant expression (K_c) for this system.
 - Calculate the concentration of all three gases at equilibrium.
 - Calculate the K_c value for this system.
 - Calculate the value of K_p at this same temperature.
2. The actual test will have a choice of two questions here (worth 20% of this part of the test).

Perbromic acid, HBrO_4 , can react with sulfuric acid, H_2SO_4 , in the following manner: $\text{HBrO}_4 + \text{H}_2\text{SO}_4 \longrightarrow \text{H}_3\text{SO}_4^+ + \text{BrO}_4^-$.

- Indicate the two conjugate acid base pairs in this reaction and label the acids in each pair.
- In the SO_4^{2-} ion, sulfur is surrounded by four oxygens in a tetrahedral structure. Indicate a Lewis structure for the H_3SO_4^+ ion.
- Is a $\text{H}_4\text{SO}_4^{2+}$ ion stable (can it exist)? Support your answer with a Lewis structure and/or discussion.
- Contrast the use of the term 'acid' as used in the Arrhenius model, in the Brønsted-Lowry model, and in the Lewis model of acids.

Part B: Time—50 minutes

Calculators may not be used on this part of the test

3. Reactions (worth 15% of this part of the test)

Write formulas of both the reactants and products for 5 of the following reactions. Unless otherwise indicated, all of the solutions are aqueous. Be sure to consider carefully if substances are ions or molecules. Do not show spectator ions. You are not required to balance the expressions. In all cases, a reaction does take place.

- Ammonia gas is added to boron trichloride gas.
- Iron (III) ions are reduced by iodide ions.
- Potassium oxide solid is added to water.
- Hydrogen peroxide solution is added to iron (II) sulfate solution.

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5. Ammonia water is added to iron (III) chloride.
6. Solid potassium chlorate is heated.
7. Concentrated ammonia solution is added to copper(II) nitrate solution.
8. Magnesium oxide solid is added to carbon dioxide.

4. Laboratory Question (worth 15% of this section of the test)

Analysis of an iron (II) solution by titration with a standardized potassium permanganate solution leads to the determination of the percent of iron in the original solution. When performing this laboratory work, the solid of known mass and containing iron (II) is dissolved in 25.0 mL of water.

- (a) Explain how each of the following affects the reported percentage of iron in the unknown solid:
 - i. The student fills the buret with KMnO_4 after rinsing with only deionized water.
 - ii. An air bubble appears in the buret tip before titration begins.
 - iii. More than 25.0 mL of water is used to dissolve the solid.
 - iv. Each time the volume of fluid is measured in the buret, measurement is made to the top of the meniscus, rather than the bottom of the meniscus.
- (b) Assuming that the accepted value for the percentage of iron in the original sample was 7.77% and that your experiment gave a result of 6.896%, determine the percentage error in your work.
- (c) Balance the reaction which occurs between iron (II) ions and the permanganate ion in acidic solution. Identify the reducing agent.

5. General Discussion (worth 15% of this part of the test)

Explain the following observations:

- (a) When a solid is heated at its melting temperature, the temperature does not increase.
- (b) The melting temperature of KCl is less than that of NaF.
- (c) Liquid bromine and ICl have almost the same molecular mass, but ICl boils at a temperature 40°C higher than Br_2 .
- (d) The boiling temperature of HCl is lower than that of HF.
- (e) When alcohol (ethanol) is poured over your arm, your skin feels cold.

6. General Discussion (worth 15% of this part of the test) The actual test will have a choice of two questions here.

For a given reaction, a proposed rate law is $\text{Rate} = k [\text{X}]^n [\text{Y}]^m$.

- (a) Explain how the values for "n" and for "m" can be determined experimentally.
- (b) If both "n" and "m" are 1, what is the overall order of this reaction?
- (c) How may the value of the rate constant, k, be changed? Support your answer.
- (d) Contrast the physical meaning of a first-order reaction with that of a zero-order reaction.
- (e) Explain why knowing the rate law expression is essential when proposing a reaction mechanism.

END OF EXAMINATION