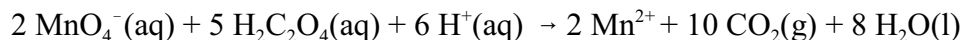
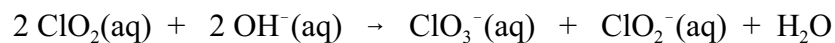


Consider the following reaction for the next two questions

1. If at a particular time, carbon dioxide was being produced at a rate of 0.010 M/min, what would be the rate of change of manganese(II) ion at the same time?
- (a) -0.002 M/min (b) -0.010 M/min (c) 0.020 M/min (d) -0.005 M/min
(e) 0.002 M/min

2. The rate law for above reaction has been determined by experiment to be $\text{rate} = k[\text{MnO}_4^-][\text{H}_2\text{C}_2\text{O}_4]$. What is the overall kinetic order of this reaction?
- (a) 20th (b) 2nd (c) 13th (d) 1st (e) 7th

3. The following data was obtained for the reaction:



initial $[\text{ClO}_2]$, M	initial $[\text{OH}^-]$, M	initial rate, M/s
0.060	0.030	0.0248
0.020	0.030	0.00276
0.020	0.090	0.00828

What is the rate law for this reaction?

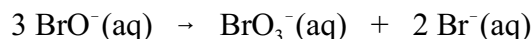
- (a) $\text{rate} = k[\text{ClO}_2]^2[\text{OH}^-]$ (b) $\text{rate} = k[\text{ClO}_2]^2[\text{OH}^-]^2$ (c) $\text{rate} = k[\text{ClO}_2]^2$
(d) $\text{rate} = k[\text{ClO}_2][\text{OH}^-]^2$ (e) $\text{rate} = k[\text{ClO}_2][\text{OH}^-]$

4. The rate law for the following reaction is $\text{rate} = k[\text{SO}_2\text{Cl}_2]$:

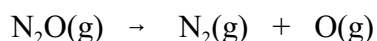


If the rate constant for this reaction is $2.20 \times 10^{-5} \text{ s}^{-1}$ at 593 K, what percent of SO_2Cl_2 will remain after 2.00 hr at this temperature?

- (a) 50% (b) 92% (c) 15% (d) 85% (e) 8%
5. The kinetics of the following reaction were studied by measuring $[\text{BrO}^-]$ vs. time. A plot of $1/[\text{BrO}^-]$ vs. time gave a straight line with a slope of $0.056 \text{ M}^{-1}\text{s}^{-1}$. What can be concluded from this information?



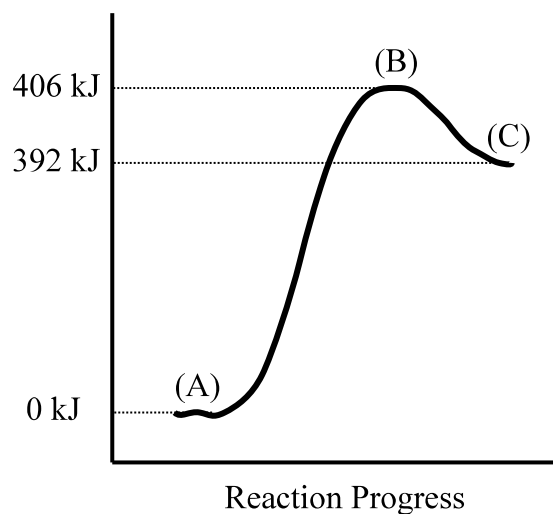
- (a) The rate law for the reaction is $\text{rate} = k[\text{BrO}_3^-]$ and $k = 0.056 \text{ M}^{-1}\text{s}^{-1}$.
(b) The rate law for the reaction is $\text{rate} = k[\text{BrO}_3^-]^3$ and $k = 17.8 \text{ Ms}$.
(c) The rate law for the reaction is $\text{rate} = k[\text{BrO}_3^-]^2$ and $k = 17.8 \text{ M}^{-1}\text{s}^{-1}$.
(d) The rate law for the reaction is $\text{rate} = k[\text{BrO}_3^-]^2$ and $k = 0.056 \text{ M}^{-1}\text{s}^{-1}$.
(e) The rate law for the reaction is $\text{rate} = k[\text{BrO}_3^-]^3$ and $k = 0.056 \text{ s}^{-1}$.
6. The activation energy for the following reaction is 250 kJ/mol and the frequency factor is $8.0 \times 10^{11} \text{ s}^{-1}$. What is the rate constant for this reaction at 1300 K?



- (a) $9.1 \times 10^{24} \text{ s}^{-1}$ (b) $1.6 \times 10^{13} \text{ s}^{-1}$ (c) 72 s^{-1} (d) $1.1 \times 10^{-3} \text{ s}^{-1}$
(e) $7.0 \times 10^{-2} \text{ s}^{-1}$

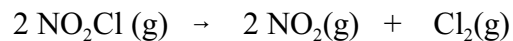
7. According to collision theory, what is the significance of the concentrations in the rate law of an elementary reaction? The term involving concentrations gives
- (a) the likelihood of reaching the transition state for the reaction.
 - (b) the probability of a collision between reactants occurring.
 - (c) the energy required for the reaction to take place.
 - (d) the rate of effective collisions.

Consider the following transition state diagram for the reaction $\text{O}_2(\text{g}) + \text{O}_2(\text{g}) \rightarrow \text{O}_3(\text{g}) + \text{O}(\text{g})$ for the next two questions.



8. What is the activation energy for the *reverse* reaction, $\text{O}_3(\text{g}) + \text{O}(\text{g}) \rightarrow \text{O}_2(\text{g}) + \text{O}_2(\text{g})$?
- (a) 14 kJ (b) -406 kJ (c) 392 kJ (d) -392 kJ (e) 406 kJ
9. What is located at point (B) in the diagram?
- (a) $\text{O}_2(\text{g}) + \text{O}_2(\text{g})$ (b) $\text{O}_3(\text{g}) + \text{O}(\text{g})$ (c) the transition state for the reaction
(d) the equilibrium state for the reaction (e) a reaction intermediate

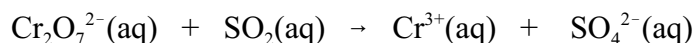
10. The rate law for the following reaction has been determined by experiment to be **rate = k[NO₂Cl]**.



Which one of the following is a possible mechanism for this reaction?

- (a) $\text{NO}_2\text{Cl}(\text{g}) \rightarrow \text{NO}(\text{g}) + \text{ClO}(\text{g})$ Slow
 $\text{NO}_2\text{Cl}(\text{g}) + \text{ClO}(\text{g}) \rightarrow \text{NO}_3(\text{g}) + \text{Cl}_2(\text{g})$ Fast
- (b) $\text{NO}_2\text{Cl}(\text{g}) \rightarrow \text{NO}_2(\text{g}) + \text{Cl}(\text{g})$ Slow
 $\text{NO}_2\text{Cl}(\text{g}) + \text{Cl}(\text{g}) \rightarrow \text{NO}_2(\text{g}) + \text{Cl}_2(\text{g})$ Fast
- (c) $2 \text{NO}_2\text{Cl}(\text{g}) \rightleftharpoons \text{N}_2\text{O}_4(\text{g}) + \text{Cl}_2(\text{g})$ Fast equilibrium
 $\text{N}_2\text{O}_4(\text{g}) \rightarrow 2 \text{NO}_2(\text{g})$ Slow
- (d) $2 \text{NO}_2\text{Cl}(\text{g}) \rightarrow \text{N}_2\text{O}_4(\text{g}) + \text{Cl}_2(\text{g})$ Slow
 $\text{N}_2\text{O}_4(\text{g}) \rightarrow 2 \text{NO}_2(\text{g})$ Fast

Consider the following *unbalanced* oxidation reduction reaction for the next 3 questions.



11. What is the oxidation number of S in SO_2 ?

- (a) -2 (b) +7 (c) +4 (d) +6 (e) 0

12. Which compounds are involved in the reduction half reaction?

- (a) $\text{SO}_2(\text{aq})$, $\text{Cr}^{3+}(\text{aq})$ (b) $\text{SO}_2(\text{aq})$, $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$ (c) $\text{SO}_2(\text{aq})$, $\text{SO}_4^{2-}(\text{aq})$
 (d) $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$, $\text{SO}_4^{2-}(\text{aq})$ (e) $\text{Cr}_2\text{O}_7^{2-}(\text{aq})$, $\text{Cr}^{3+}(\text{aq})$

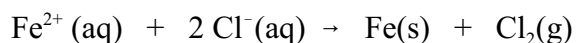
13. The complete balanced equation in **ACIDIC** media for the reaction has the following stoichiometry coefficients. (Note that some of the values may be 0 indicating that the compound does not appear!)



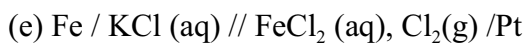
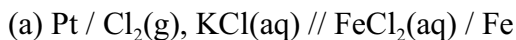
The stoichiometry coefficients, in order are

- (a) 3,1,0,2,0 → 3,2,1,0,0 (b) 1,3,1,0,0 → 2,3,0,0,2
 (c) 3,1,1,0,0 → 3,2,0,0,2 (d) 1,3,0,2,0 → 2,3,1,0,0
 (e) 1,1,0,10,0 → 2,1,5,0,0

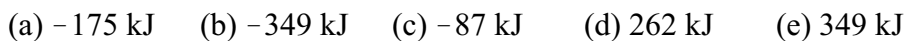
Consider the following reaction for the next two questions.



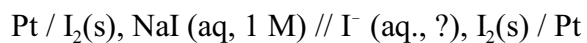
14. In which of the following cells will the above reaction be the overall reaction occurring when current flows?



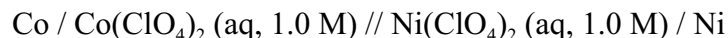
15. Use E° values to calculate ΔG° for this reaction.



16. The following concentration cell was constructed in order to measure [I⁻]. If E_{cell} is measured to be 0.328 V, what is [I⁻] in the right side compartment?



Consider the following electrochemical cell for the next 4 questions.



17. What is the name of the ionic compound in the cathode compartment?
- (a) cobalt chloride (b) nickel(II) perchlorate (c) nickel(IV) chlorate
(d) copper(II) chlorate (e) cobalt(II) perchlorate
18. What is E° cell?
- (a) -0.534 V (b) 0.534 V (c) 0.020 V (d) 0.443 V (e) -0.020 V (ab) -0.443 V
19. What is the reaction occurring in the cell when current flows?
- (a) $\text{Co}(\text{s}) + \text{Ni}(\text{s}) \rightarrow \text{Co}^{2+}(\text{aq}) + \text{Ni}^{2+}(\text{aq})$
(b) $\text{Co}^{2+}(\text{aq}) + \text{Ni}(\text{s}) \rightarrow \text{Co}(\text{s}) + \text{Ni}^{2+}(\text{aq})$
(c) $\text{Co}(\text{s}) + \text{Co}^{2+}(\text{aq}) \rightarrow \text{Ni}(\text{s}) + \text{Ni}^{2+}(\text{aq})$
(d) $\text{Co}(\text{s}) + \text{Ni}^{2+}(\text{aq}) \rightarrow \text{Co}^{2+}(\text{aq}) + \text{Ni}(\text{s})$
20. What will be the concentrations in the cell be when the reaction occurring in the cell reaches equilibrium? (The A question. Hint: You will need to set up a reaction table to determine expressions for the concentrations. What is E_{cell} at equilibrium?)
- (a) $[\text{Co}^{2+}] = 0.35 \text{ M}$ $[\text{Ni}^{2+}] = 1.65 \text{ M}$ (b) $[\text{Co}^{2+}] = 0.50 \text{ M}$ $[\text{Ni}^{2+}] = 1.25 \text{ M}$
(c) $[\text{Co}^{2+}] = 1.25 \text{ M}$ $[\text{Ni}^{2+}] = 0.50 \text{ M}$ (d) $[\text{Co}^{2+}] = 1.65 \text{ M}$ $[\text{Ni}^{2+}] = 0.35 \text{ M}$
(e) $[\text{Co}^{2+}] = 1.90 \text{ M}$ $[\text{Ni}^{2+}] = 0.10 \text{ M}$

Answers: 1 e, 2 b, 3 a, 4 d, 5 d, 6 c, 7 b, 8 a, 9 c, 10 b, 11 c, 12 e, 13 d, 14 a, 15 e, 16 d, 17 b, 18 c, 19 d, 20 d.

EQUATIONS and ADDITIONAL INFO

$$E_{cell} = E_{cat} - E_{an} \quad oO + ne^- \rightleftharpoons rR$$

$$\Delta G = -nFE_{cell} \quad E = E^\circ - \frac{0.0592V}{n} \log \frac{[R]^r}{[O]^o} \quad \text{at } 25^\circ C$$

$$\Delta G^\circ = -RT \ln K \quad \text{or} \quad \Delta G^\circ = -2.303 RT \log K$$

$$K = e^{-\frac{\Delta G^\circ}{RT}} \quad \text{or} \quad K = 10^{-\frac{\Delta G^\circ}{2.303RT}}$$

$$\ln \left(\frac{[A]_t}{[A]_0} \right) = -kt \quad \text{or} \quad \log \left(\frac{[A]_t}{[A]_0} \right) = -\frac{kt}{2.303}$$

$$\ln[A]_t = -kt + \ln[A]_0 \quad \text{or} \quad \log[A]_t = -kt/2.303 + \log[A]_0$$

$$1/[A]_t = kt + 1/[A]_0$$

$$k = A e^{-E_a/(RT)} \quad \ln k = \ln A - (E_a/R)(1/T)$$

$$F = 96485 \text{ coul/mol} \quad R = 8.314 \times 10^{-3} \text{ kJ/(mol}\cdot\text{K)} \quad \text{Volt} = \text{Joule/coul} \quad 0^\circ \text{C} = 273.15 \text{ K}$$

Standard Electrode Potentials at 25°C

<u>Half Reaction</u>	<u>E° (V)</u>
Ag ⁺ (aq) + e ⁻ ⇌ Ag(s)	+0.80 V
AgCl(s) + e ⁻ ⇌ Ag(s) + Cl ⁻ (aq)	+0.2223 V
AgBr(s) + e ⁻ ⇌ Ag(s) + Br ⁻ (aq)	+0.07 V
Br ₂ (l) + 2 e ⁻ ⇌ 2 Br ⁻ (aq)	+1.09 V
Cl ₂ (g) + 2 e ⁻ ⇌ 2 Cl ⁻ (aq)	+1.36 V
Co ²⁺ (aq) + 2 e ⁻ ⇌ Co(s)	-0.277 V
Cu ⁺ (aq) + e ⁻ ⇌ Cu(s)	+0.52 V
Cu ²⁺ (aq) + 2 e ⁻ ⇌ Cu(s)	+0.34 V
Cu ²⁺ (aq) + e ⁻ ⇌ Cu ⁺ (aq)	+0.159 V
Cu ²⁺ (aq) + 2 CN ⁻ (aq) + e ⁻ ⇌ Cu(CN) ₂ ⁻ (aq)	+1.12 V
Fe ²⁺ (aq) + 2 e ⁻ ⇌ Fe(s)	-0.45 V
Fe ³⁺ (aq) + e ⁻ ⇌ Fe ²⁺ (aq)	+0.77 V
2 H ⁺ (aq) + 2 e ⁻ ⇌ H ₂ (g)	0.000V
2 H ₂ O(aq) + 2 e ⁻ ⇌ H ₂ (g) + 2 OH ⁻ (aq)	-0.828 V
2 Hg ²⁺ (aq) + 2 e ⁻ ⇌ 2 Hg ₂ ²⁺	0.905 V
Hg ₂ ²⁺ (aq) + 2 e ⁻ ⇌ 2 Hg(l)	0.7961 V
Hg ₂ SO ₄ (s) + 2 e ⁻ ⇌ 2 Hg(l) + SO ₄ ²⁻	0.6158 V
I ₂ (s) + 2 e ⁻ ⇌ 2 I ⁻ (aq)	+0.54 V
Mg ²⁺ (aq) + 2 e ⁻ ⇌ Mg(s)	-2.37 V
Ni ²⁺ (aq) + 2 e ⁻ ⇌ Ni(s)	-0.257 V
Ni(OH) ₂ (s) + 2 e ⁻ ⇌ Ni(s) + 2 OH ⁻ (aq)	-0.72 V
Pb ²⁺ (aq) + 2 e ⁻ ⇌ Pb(s)	-0.126 V
PbO ₂ (s) + 3 H ⁺ (aq) + HSO ₄ ⁻ (aq) + 2 e ⁻ ⇌ PbSO ₄ (s) + 2 H ₂ O(l)	+1.628 V
PbSO ₄ (s) + H ⁺ + 2 e ⁻ ⇌ Pb(s) + HSO ₄ ⁻	-0.296 V
S ₂ O ₈ ²⁻ (aq) + 2 e ⁻ ⇌ 2 SO ₄ ²⁻ (aq)	+2.01 V
Sn ⁴⁺ (aq) + 2 e ⁻ ⇌ Sn ²⁺	+0.15 V
Sn ²⁺ (aq) + 2 e ⁻ ⇌ Sn(s)	-0.138 V
Zn ²⁺ (aq) + 2 e ⁻ ⇌ Zn(s)	-0.76 V