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Chemistry 12

JUNE 2002

Course Code = CH

### Student Instructions

1. Place the stickers with your Personal Education Number (PEN) in the allotted spaces above. **Under no circumstance is your name or identification, other than your Personal Education Number, to appear on this booklet.**
2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.
3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.
4. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by **END OF EXAMINATION**.
5. At the end of the examination, place your Response Form inside the front cover of this booklet and return the booklet and your Response Form to the supervisor.

Question 1:  
1.  .   
(3)

Question 8:  
8.  .   
(2)

Question 2:  
2.  .   
(2)

Question 9:  
9.  .   
(5)

Question 3:  
3.  .   
(2)

Question 10:  
10.  .   
(3)

Question 4:  
4.  .   
(4)

Question 11:  
11.  .   
(4)

Question 5:  
5.  .   
(3)

Question 12:  
12.  .   
(3)

Question 6:  
6.  .   
(3)

Question 13:  
13.  .   
(2)

Question 7:  
7.  .   
(4)

# **CHEMISTRY 12**

**JUNE 2002**

COURSE CODE = CH

## GENERAL INSTRUCTIONS

1. Aside from an approved calculator, electronic devices, including dictionaries and pagers, are **not** permitted in the examination room.
2. All multiple-choice answers must be entered on the Response Form using an **HB pencil**. Multiple-choice answers entered in this examination booklet will **not** be marked.
3. For each of the written-response questions, write your answer in the space provided in this booklet.
4. Ensure that you use language and content appropriate to the purpose and audience of this examination. Failure to comply may result in your paper being awarded a zero.
5. This examination is designed to be completed in **two hours**. *Students may, however, take up to 30 minutes of additional time to finish.*

## CHEMISTRY 12 PROVINCIAL EXAMINATION

	<b>Value</b>	<b>Suggested Time</b>
1. This examination consists of <b>two</b> parts:		
PART A: 48 multiple-choice questions	60	70
PART B: 13 written-response questions	40	50
<b>Total:</b>	<b>100 marks</b>	<b>120 minutes</b>

2. The following tables can be found in the separate **Data Booklet**:

- Periodic Table of the Elements
- Atomic Masses of the Elements
- Names, Formulae, and Charges of Some Common Ions
- Solubility of Common Compounds in Water
- Solubility Product Constants at 25°C
- Relative Strengths of Brønsted-Lowry Acids and Bases
- Acid-Base Indicators
- Standard Reduction Potentials of Half-cells

No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions and may also include graphing functions. Computers, calculators with a QWERTY keyboard, and electronic writing pads will not be allowed. Students must not bring any external devices to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, or external keyboards. Students may have more than one calculator available during the examination. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

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## PART A: MULTIPLE CHOICE

Value: 60 marks

Suggested Time: 70 minutes

**INSTRUCTIONS:** For each question, select the **best** answer and record your choice on the Response Form provided. Using an HB pencil, completely fill in the circle that has the letter corresponding to your answer.

Selected multiple-choice questions are worth 2 marks.

1. Which of the following has the lowest rate of reaction? (1 mark)

- A.  $\text{Pb}_{(s)} + \text{CuCl}_{2(aq)} \rightarrow \text{Cu}_{(s)} + \text{PbCl}_{2(aq)}$
- B.  $\text{HCl}_{(aq)} + \text{NaOH}_{(aq)} \rightarrow \text{H}_2\text{O}_{(\ell)} + \text{NaCl}_{(aq)}$
- C.  $\text{H}_2\text{SO}_{4(aq)} + \text{Ba}(\text{OH})_{2(aq)} \rightarrow 2\text{H}_2\text{O}_{(\ell)} + \text{BaSO}_{4(s)}$
- D.  $\text{Pb}(\text{NO}_3)_{2(aq)} + 2\text{NaI}_{(aq)} \rightarrow \text{PbI}_{2(s)} + 2\text{NaNO}_{3(aq)}$

2. Which of the following affects the rate of heterogeneous reactions, but does not affect the rate of homogeneous reactions? (1 mark)

- A. catalyst
- B. temperature
- C. surface area
- D. concentration

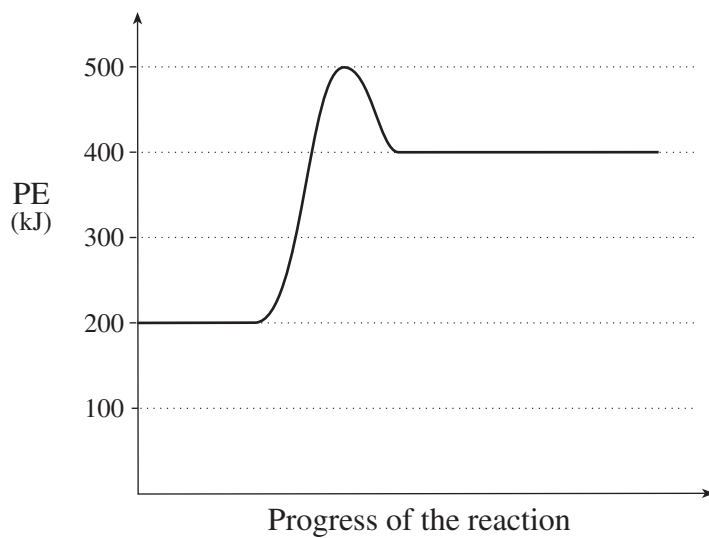
3. As reactant particles approach each other, what changes occur in KE and PE? (1 mark)

	KE	PE
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

OVER

4. Consider the following PE diagram:

(1 mark)



What is the minimum potential energy required to change reactants to the activated complex?

- A. 200 kJ
- B. 300 kJ
- C. 400 kJ
- D. 500 kJ

5. Consider the following reaction mechanism:

(1 mark)

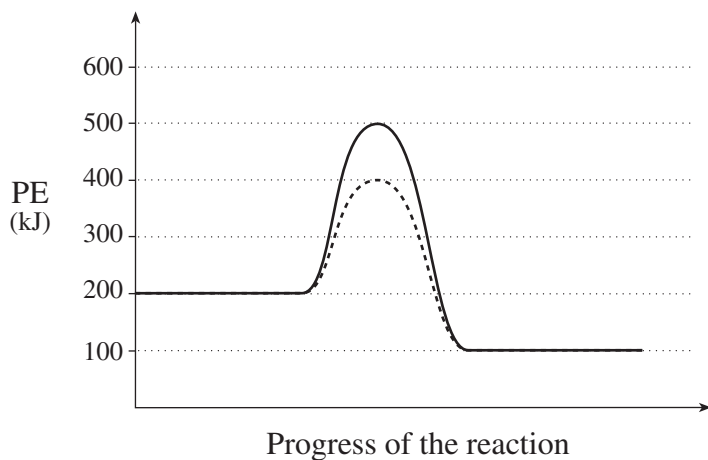
Step 1	$2\text{NO}_2 \rightarrow \text{NO}_3 + \text{NO}$
Step 2	$\text{NO}_3 + \text{CO} \rightarrow \text{NO}_2 + \text{CO}_2$

Identify a product in the overall reaction.

- A. CO
- B. CO<sub>2</sub>
- C. NO<sub>2</sub>
- D. NO<sub>3</sub>

6. Consider the following PE diagram for a catalyzed and uncatalyzed reaction:

(2 marks)

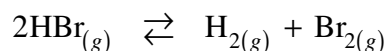


Which of the following describes the **reverse** reaction?

	Reverse Reaction	Activation Energy (kJ)	$\Delta H$ (kJ)
A.	uncatalyzed	300	-100
B.	catalyzed	300	-100
C.	uncatalyzed	400	+100
D.	catalyzed	400	+100

7. Consider the following:

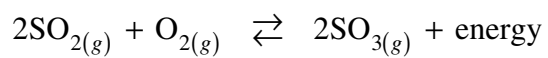
(1 mark)



Initially, HBr is added to an empty flask. How do the rate of the forward reaction and the [HBr] change as the system proceeds to equilibrium?

	Forward Rate	[HBr]
A.	decreases	decreases
B.	decreases	increases
C.	increases	increases
D.	increases	decreases

Use the following equilibrium equation to answer questions 8 and 9.



8. Which of the following two stresses will each cause the system to shift to the right?

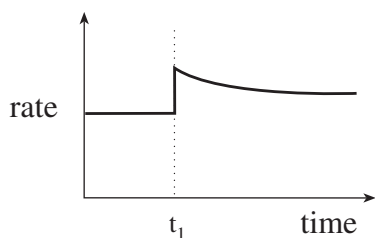
(1 mark)

- A. decrease temperature, decrease  $[\text{O}_2]$
- B. increase temperature, increase  $[\text{SO}_3]$
- C. increase temperature, decrease  $[\text{SO}_3]$
- D. decrease temperature, increase  $[\text{SO}_2]$

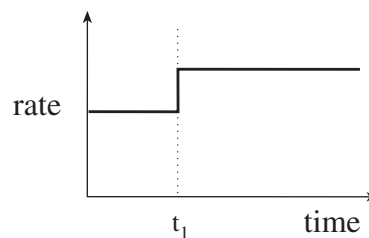
9. Which of the following graphs shows the **reverse** rate of reaction when a catalyst is added to the equilibrium at time =  $t_1$  ?

(1 mark)

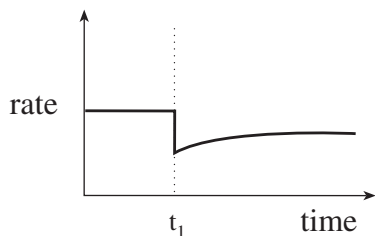
A.



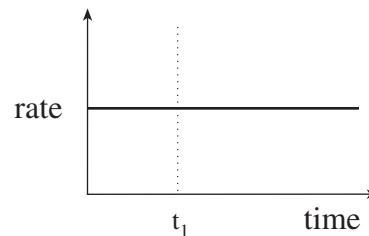
B.



C.

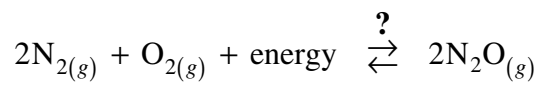


D.



10. Consider the following:

(2 marks)

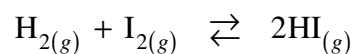


What positions do minimum enthalpy and maximum entropy tend toward?

	Minimum Enthalpy	Maximum Entropy
A.	products	products
B.	products	reactants
C.	reactants	products
D.	reactants	reactants

11. Consider the following:

(1 mark)

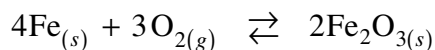


Initially, some HI is placed into a 1.0 L container. At equilibrium there is 0.010 mol  $\text{H}_2$ , 0.010 mol  $\text{I}_2$  and 0.070 mol HI present. How many moles of HI were initially added to the container?

- A. 0.060 mol
- B. 0.070 mol
- C. 0.080 mol
- D. 0.090 mol

12. What is the equilibrium expression for the following system?

(1 mark)



- A.  $K_{eq} = [\text{O}_2]^3$
- B.  $K_{eq} = \frac{1}{[\text{O}_2]^3}$
- C.  $K_{eq} = \frac{[\text{Fe}_2\text{O}_3]^2}{[\text{Fe}]^4[\text{O}_2]^3}$
- D.  $K_{eq} = \frac{[2\text{Fe}_2\text{O}_3]}{[4\text{Fe}][3\text{O}_2]}$

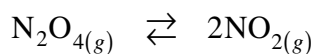
13. What will cause the value of  $K_{eq}$  for an endothermic reaction to increase?

(1 mark)

- A. increasing [products]
- B. decreasing [products]
- C. increasing the temperature
- D. decreasing the temperature

14. Consider the following equilibrium:

(2 marks)



An equilibrium mixture contains  $4.0 \times 10^{-2}$  mol  $\text{N}_2\text{O}_4$  and  $1.5 \times 10^{-2}$  mol  $\text{NO}_2$  in a 1.0 L flask. What is the value of  $K_{eq}$  ?

- A.  $5.6 \times 10^{-3}$
- B.  $3.8 \times 10^{-1}$
- C.  $7.5 \times 10^{-1}$
- D.  $1.8 \times 10^2$

15. In every solubility equilibrium, the rate of dissolving is (1 mark)
- A. equal to zero.
  - B. equal to the rate of crystallization.
  - C. less than the rate of crystallization.
  - D. greater than the rate of crystallization.
16. A 3.0 L solution of  $\text{BaCl}_2$  has a chloride ion concentration of 0.20 M. The barium ion concentration in this solution is (1 mark)
- A. 0.067 M
  - B. 0.10 M
  - C. 0.20 M
  - D. 0.60 M
17. Which of the following has the lowest solubility? (2 marks)
- A.  $\text{CaS}$
  - B.  $\text{CuS}$
  - C.  $\text{FeS}$
  - D.  $\text{MgS}$
18. What is the formula equation for the reaction that occurs when equal volumes of 0.20 M  $\text{K}_3\text{PO}_4$  and 0.20 M  $\text{ZnCl}_2$  are mixed together? (1 mark)
- A.  $\text{K}^+_{(aq)} + \text{Cl}^-_{(aq)} \rightarrow \text{KCl}_{(s)}$
  - B.  $3\text{Zn}^{2+}_{(aq)} + 2\text{PO}_4^{3-}_{(aq)} \rightarrow \text{Zn}_3(\text{PO}_4)_2_{(s)}$
  - C.  $2\text{K}_3\text{PO}_4_{(aq)} + 3\text{ZnCl}_2_{(aq)} \rightarrow \text{Zn}_3(\text{PO}_4)_2_{(s)} + 6\text{KCl}_{(aq)}$
  - D.  $2\text{K}_3\text{PO}_4_{(aq)} + 3\text{ZnCl}_2_{(aq)} \rightarrow 3\text{Zn}_3(\text{PO}_4)_2_{(aq)} + 6\text{KCl}_{(s)}$

OVER

19. Which of the following could be added to a sample of hard water to remove both  $0.2\text{ M Ca}^{2+}$  and  $0.2\text{ M Mg}^{2+}$  ? **(1 mark)**
- A.  $0.2\text{ M S}^{2-}$
  - B.  $0.2\text{ M Cl}^{-}$
  - C.  $0.2\text{ M OH}^{-}$
  - D.  $0.2\text{ M SO}_4^{2-}$
20. The  $K_{sp}$  expression for a saturated solution of  $\text{Ag}_2\text{SO}_3$  is **(1 mark)**
- A.  $K_{sp} = [2\text{Ag}^+][\text{SO}_3^{2-}]$
  - B.  $K_{sp} = [\text{Ag}^+]^2[\text{SO}_3^{2-}]$
  - C.  $K_{sp} = [\text{Ag}_2^{2+}][\text{SO}_3^{2-}]$
  - D.  $K_{sp} = [2\text{Ag}^+]^2[\text{SO}_3^{2-}]$
21. The solubility of  $\text{CaF}_2$  is  $3.3 \times 10^{-4}\text{ M}$ . Determine the  $K_{sp}$  value of  $\text{CaF}_2$  . **(2 marks)**
- A.  $3.6 \times 10^{-11}$
  - B.  $1.4 \times 10^{-10}$
  - C.  $1.1 \times 10^{-7}$
  - D.  $3.3 \times 10^{-4}$
22. What is the maximum  $[\text{Ag}^+]$  that can exist in a solution of  $0.010\text{ M NaIO}_3$  ? **(1 mark)**
- A.  $3.2 \times 10^{-10}\text{ M}$
  - B.  $3.2 \times 10^{-8}\text{ M}$
  - C.  $3.2 \times 10^{-6}\text{ M}$
  - D.  $1.8 \times 10^{-4}\text{ M}$

23. An *Arrhenius base* is defined as a substance that (1 mark)

- A. releases  $\text{H}^+_{(aq)}$
- B. releases  $\text{OH}^-_{(aq)}$
- C. accepts a proton
- D. donates a proton

24. The conjugate acid of  $\text{HAsO}_4^{2-}$  is (1 mark)

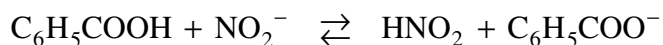
- A.  $\text{AsO}_4^{3-}$
- B.  $\text{AsO}_4^{2-}$
- C.  $\text{H}_2\text{AsO}_4^-$
- D.  $\text{H}_2\text{AsO}_4^{2-}$

25. Which of the following will have the greatest electrical conductivity? (1 mark)

- A. 1.0 M HF
- B. 1.0 M HBr
- C. 1.0 M HCN
- D. 1.0 M  $\text{H}_2\text{SO}_3$

26. Consider the equilibrium:

(2 marks)



Identify the stronger acid and predict whether reactants or products are favoured.

	Stronger Acid	Side Favoured
A.	$\text{HNO}_2$	reactants
B.	$\text{HNO}_2$	products
C.	$\text{C}_6\text{H}_5\text{COOH}$	reactants
D.	$\text{C}_6\text{H}_5\text{COOH}$	products

27. Which of the following represents the equilibrium expression for the ionization of water?

(1 mark)

A.  $K_w = [\text{H}_3\text{O}^+][\text{OH}^-]$

B.  $K_w = \frac{1}{[\text{H}_3\text{O}^+][\text{OH}^-]}$

C.  $K_w = [\text{H}_3\text{O}^+] + [\text{OH}^-]$

D.  $K_w = \frac{[\text{H}_3\text{O}^+][\text{OH}^-]}{[\text{H}_2\text{O}]}$

28. Determine the pH of 3.0 M KOH .

(2 marks)

- A. 0.48
- B. 11.00
- C. 13.52
- D. 14.48

29. Four acids are analyzed and their  $K_a$  values are determined. Which of the following values represents the strongest acid?

(1 mark)

- A.  $K_a = 2.2 \times 10^{-13}$
- B.  $K_a = 6.2 \times 10^{-8}$
- C.  $K_a = 1.7 \times 10^{-5}$
- D.  $K_a = 1.2 \times 10^{-2}$

30. The dissociation of  $\text{NH}_4\text{NO}_3$  is represented by

(1 mark)

- A.  $\text{NH}_4\text{NO}_{3(s)} \rightarrow \text{NH}_4^+_{(aq)} + \text{NO}_3^-_{(aq)}$
- B.  $\text{NH}_4^+_{(aq)} + \text{NO}_3^-_{(aq)} \rightarrow \text{NH}_4\text{NO}_{3(s)}$
- C.  $\text{NH}_4^+_{(aq)} + \text{H}_2\text{O}_{(\ell)} \rightarrow \text{H}_3\text{O}^+_{(aq)} + \text{NH}_{3(aq)}$
- D.  $\text{NO}_3^-_{(aq)} + \text{H}_2\text{O}_{(\ell)} \rightarrow \text{HNO}_{3(aq)} + \text{OH}^-_{(aq)}$

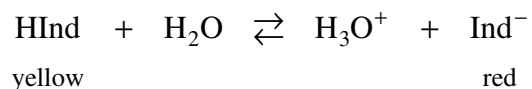
31. A solution of  $\text{Al}(\text{NO}_3)_3$  will be

(1 mark)

- A. basic.
- B. acidic.
- C. neutral.
- D. amphiprotic.

32. Consider the following equilibrium for the chemical indicator phenol red, HInd, at a pH = 7.3 (orange) .

**(2 marks)**



When some NaOH is added, what stress is imposed on the equilibrium and what colour change occurs?

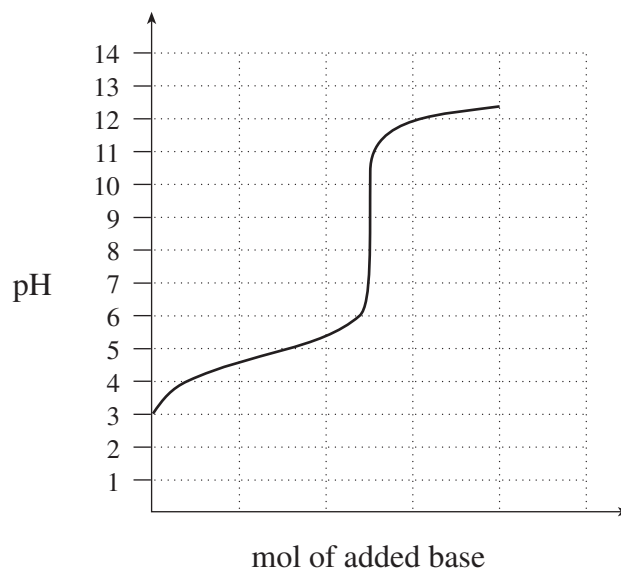
	Stress	Indicator Colour Change
A.	increased $[\text{H}_3\text{O}^+]$	turns red
B.	decreased $[\text{H}_3\text{O}^+]$	turns red
C.	increased $[\text{H}_3\text{O}^+]$	turns yellow
D.	decreased $[\text{H}_3\text{O}^+]$	turns yellow

33. A chemical indicator has a  $K_a = 2.5 \times 10^{-5}$ . Determine the pH at the transition point.

**(1 mark)**

- A. 2.30
- B. 4.60
- C. 7.00
- D. 9.40

34. Consider the following titration curve:



Select a suitable indicator for this titration.

**(1 mark)**

- A. orange IV
- B. methyl red
- C. thymolphthalein
- D. indigo carmine

35. Calculate the volume of 0.300 M  $\text{HNO}_3$  needed to completely neutralize 25.0 mL of 0.250 M  $\text{Sr}(\text{OH})_2$ .

**(2 marks)**

- A. 10.4 mL
- B. 15.0 mL
- C. 20.8 mL
- D. 41.7 mL

36. Equal moles of which of the following chemicals could be used to make a basic buffer solution?

**(1 mark)**

- A. HF and NaOH
- B. HCl and NaCl
- C. KBr and  $\text{NaNO}_3$
- D.  $\text{NH}_3$  and  $\text{NH}_4\text{Cl}$

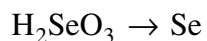
37. Which reaction occurs when calcium oxide is added to water? **(1 mark)**

- A.  $2\text{CaO}_{(s)} \rightarrow \text{Ca}_2\text{O}_{2(aq)}$
- B.  $2\text{CaO}_{(s)} \rightarrow 2\text{Ca}_{(aq)} + \text{O}_{2(aq)}$
- C.  $\text{CaO}_{(s)} + \text{H}_2\text{O}_{(\ell)} \rightarrow \text{Ca}(\text{OH})_{2(aq)}$
- D.  $\text{CaO}_{(s)} + \text{H}_2\text{O}_{(\ell)} \rightarrow \text{CaOH}_{(aq)} + \text{O}_{2(aq)}$

38. Which of the following is the strongest reducing agent? **(1 mark)**

- A.  $\text{H}_2\text{S}$
- B.  $\text{H}_2\text{O}$
- C.  $\text{H}_2\text{Se}$
- D.  $\text{H}_2\text{Te}$

39. Consider the following unbalanced half-reaction: **(2 marks)**



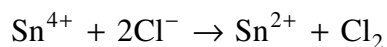
The oxidation number of Se

- A. increases as it undergoes oxidation.
- B. increases as it undergoes reduction.
- C. decreases as it undergoes oxidation.
- D. decreases as it undergoes reduction.

40. Which of the following will react spontaneously with  $\text{Br}_2$  but not with  $\text{I}_2$  ? **(1 mark)**

- A.  $\text{F}^-$
- B.  $\text{Cr}^{2+}$
- C.  $\text{Fe}^{2+}$
- D.  $\text{Mn}^{2+}$

41. Consider the following: **(1 mark)**



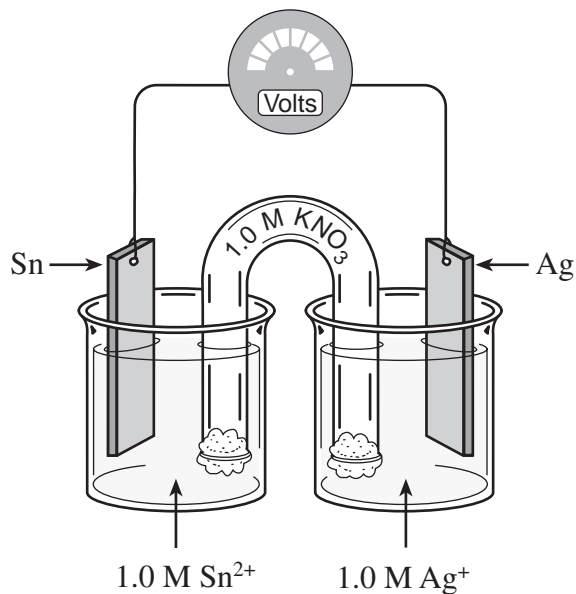
What is true for this reaction?

- A.  $E^\circ_{\text{cell}} = +1.51 \text{ V}$  and it is spontaneous.
- B.  $E^\circ_{\text{cell}} = +1.21 \text{ V}$  and it is spontaneous.
- C.  $E^\circ_{\text{cell}} = -1.21 \text{ V}$  and it is non-spontaneous.
- D.  $E^\circ_{\text{cell}} = -1.51 \text{ V}$  and it is non-spontaneous.

42. What is the function of the salt bridge in an electrochemical cell? **(1 mark)**

- A. It provides a path for electrons.
- B. It maintains electrical neutrality in each half cell.
- C. It allows the anode to become positively charged.
- D. It allows the cathode to become negatively charged.

Use the following diagram to answer questions 43, 44 and 45.



43. In the above electrochemical cell, how do the mass of the anode and the  $[Ag^+]$  change as the cell operates? (2 marks)

	Mass of the Anode	$[Ag^+]$
A.	decreases	increases
B.	increases	increases
C.	decreases	decreases
D.	no change	decreases

44. What is the overall cell reaction? (1 mark)

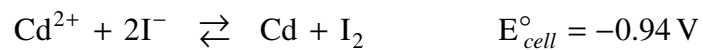
- A.  $2Ag + Sn^{2+} \rightarrow Sn + 2Ag^+$   
 B.  $2Ag + Sn \rightarrow Sn^{2+} + 2Ag^+$   
 C.  $2Ag^+ + Sn^{2+} \rightarrow Sn + 2Ag$   
 D.  $2Ag^+ + Sn \rightarrow Sn^{2+} + 2Ag$

45. What is the value of  $E^\circ$  for the cell? (1 mark)

- A.  $-0.94\text{ V}$   
 B.  $-0.66\text{ V}$   
 C.  $+0.66\text{ V}$   
 D.  $+0.94\text{ V}$

46. Consider the following equation:

(1 mark)



What is  $E^{\circ}$  for the reduction of  $\text{Cd}^{2+}$  ?

- A.  $-0.40 \text{ V}$
- B.  $-0.14 \text{ V}$
- C.  $+0.14 \text{ V}$
- D.  $+0.40 \text{ V}$

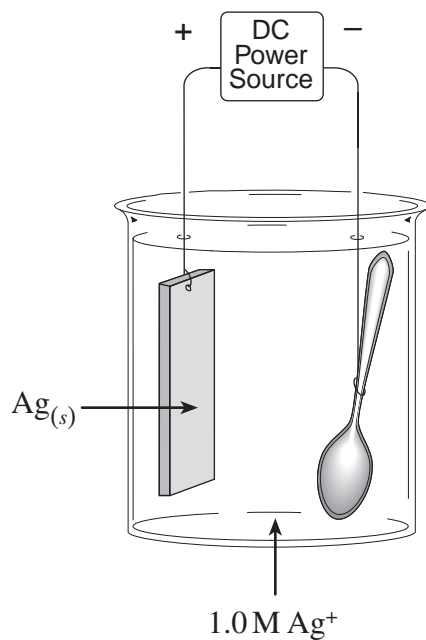
47. Which of the following describes an operating electrochemical cell?

(2 marks)

	$E^{\circ}$	Type of Reaction	Direction of Electron Flow
A.	positive	spontaneous	anode to cathode
B.	negative	spontaneous	cathode to anode
C.	positive	non-spontaneous	anode to cathode
D.	negative	non-spontaneous	cathode to anode

OVER

48. A copper spoon is plated with silver in an electrolytic cell.



What is the reaction at the anode?

(1 mark)

- A.  $\text{Ag} \rightarrow \text{Ag}^+ + \text{e}^-$
- B.  $\text{Ag}^+ + \text{e}^- \rightarrow \text{Ag}$
- C.  $\text{Cu} \rightarrow \text{Cu}^{2+} + 2\text{e}^-$
- D.  $\text{Cu}^{2+} + 2\text{e}^- \rightarrow \text{Cu}$

**This is the end of the multiple-choice section.**  
**Answer the remaining questions directly in this examination booklet.**

## PART B: WRITTEN RESPONSE

Value: 40 marks

Suggested Time: 50 minutes

**INSTRUCTIONS:** You will be expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner.

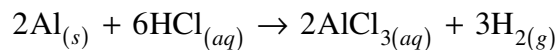
Your steps and assumptions leading to a solution must be written in the spaces below the questions.

Answers must include units where appropriate and be given to the correct number of significant figures.

**For questions involving calculations, full marks will NOT be given for providing only an answer.**

1. Consider the reaction:

(3 marks)



A 10.0 g sample of Al reacts completely in excess HCl in 300.0 s.

What is the rate of production of H<sub>2</sub> in mol/s ?

OVER

2. Using collision theory, give **two** reasons why reactions occur more rapidly at a higher temperature. **(2 marks)**

i) \_\_\_\_\_  
\_\_\_\_\_

ii) \_\_\_\_\_  
\_\_\_\_\_

3. Chemical reactions tend toward a position of minimum enthalpy and maximum entropy.

a) What is meant by the term *enthalpy*? **(1 mark)**

\_\_\_\_\_

b) What is meant by the term *entropy*? **(1 mark)**

\_\_\_\_\_

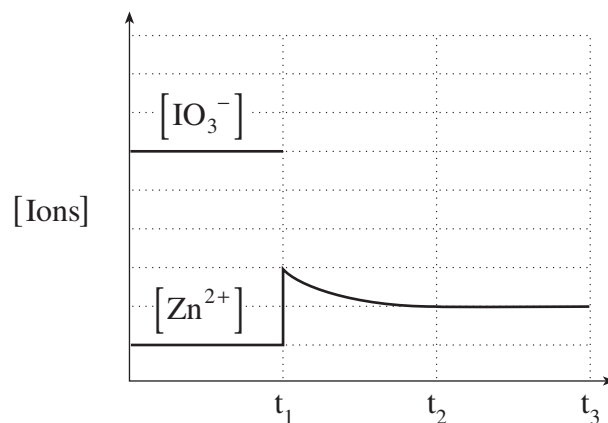
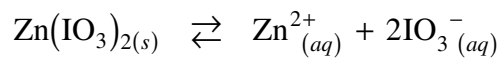
4. Consider the following:

**(4 marks)**



Initially, 0.080 mol  $\text{H}_2$  and 0.080 mol  $\text{Br}_2$  are placed into a 4.00 L container.  
What is the  $[\text{HBr}]$  at equilibrium?

5. Consider the following equilibrium and accompanying graph:



a) Identify the stress applied at  $t_1$ . **(1 mark)**

b) Complete the above graph from  $t_1$  to  $t_3$  for the  $[\text{IO}_3^-]$ . **(2 marks)**

6. Calculate the solubility of  $\text{SrSO}_4$  in grams per litre. **(3 marks)**

7. The cyanide ion,  $\text{CN}^-$ , is a Brønsted-Lowry base.

a) Define *Brønsted-Lowry base*.

**(1 mark)**

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b) Write the equation representing the reaction of  $\text{CN}^-$  with water.

**(2 marks)**

c) Identify a conjugate pair in b) above.

**(1 mark)**

8. Write an equation to show the ionization of water.

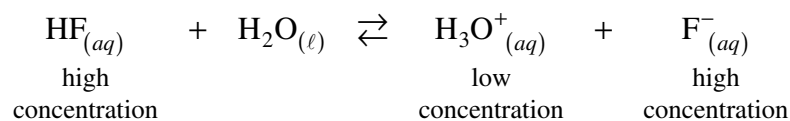
**(2 marks)**

9. Calculate the pH of 1.50 M  $\text{NH}_3$  .

**(5 marks)**

10. Consider the following buffer equilibrium:

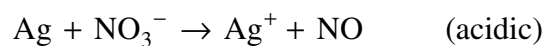
(3 marks)



Using Le Châtelier's Principle, explain what happens to the pH of the buffer solution when a small amount of NaOH is added.

11. Balance the following redox equation:

(4 marks)



12. Draw a diagram of an operating electrolytic cell used to extract pure lead from an impure lead sample. Identify the electrolyte and the material used for the anode. **(3 marks)**

13. A sample of copper is placed in  $\text{HNO}_{3(aq)}$  and another sample of copper is placed in  $\text{HCl}_{(aq)}$ .

a) In which acid does the copper react?

**( $\frac{1}{2}$  mark)**

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b) Calculate  $E^\circ$  for the reaction that occurs.

**( $1\frac{1}{2}$  marks)**

**END OF EXAMINATION**

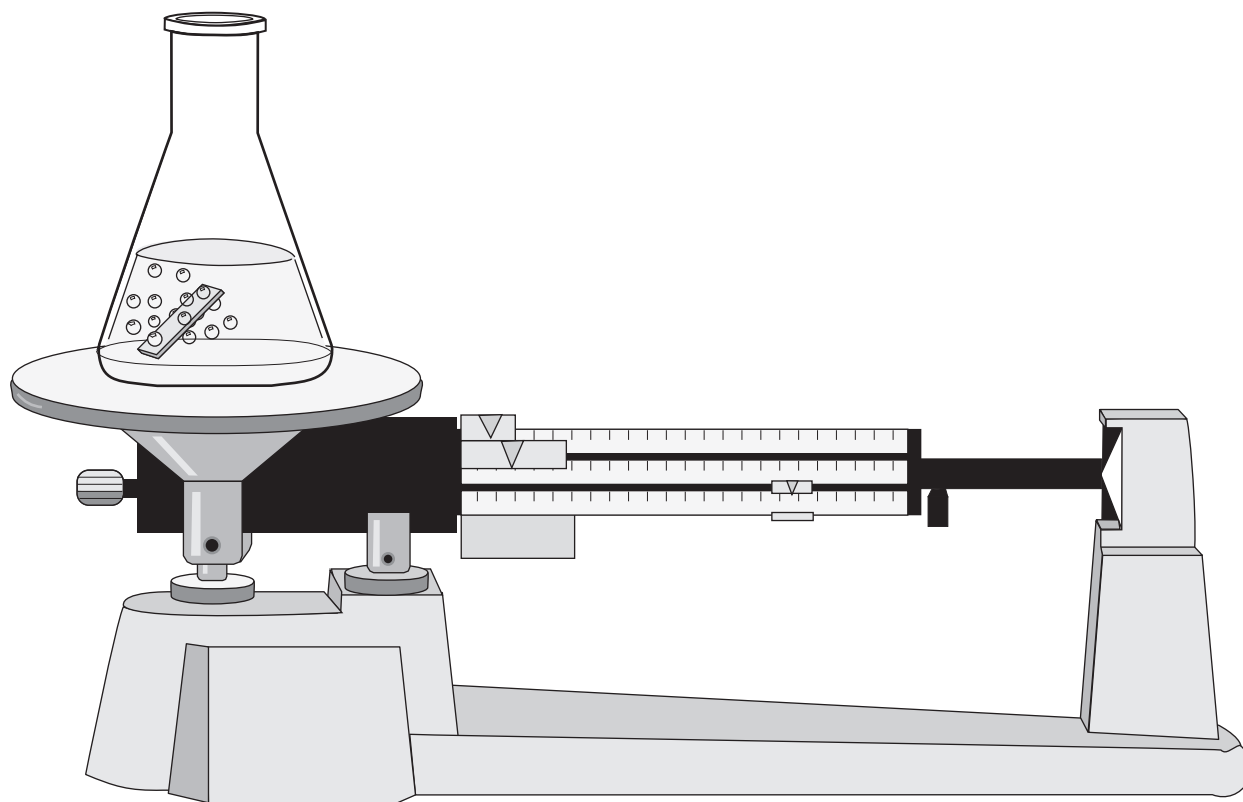
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# Data Booklet

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## CHEMISTRY 12

Work done in this booklet  
will not be marked.



# CONTENTS

Page	Table
1	Periodic Table of the Elements
2	Atomic Masses of the Elements
3	Names, Formulae, and Charges of Some Common Ions
4	Solubility of Common Compounds in Water
5	Solubility Product Constants at 25°C
6	Relative Strengths of Brønsted-Lowry Acids and Bases
7	Acid-base Indicators
8	Standard Reduction Potentials of Half-cells

## REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80<sup>th</sup> edition, CRC Press, Boca Raton, 1999.

# PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18		
1 <b>H</b> Hydrogen 1.0	4 <b>Be</b> Beryllium 9.0		22 <b>Ti</b> Titanium 47.9		24 <b>Cr</b> Chromium 52.0		26 <b>Fe</b> Iron 55.8		28 <b>Ni</b> Nickel 58.7		30 <b>Zn</b> Zinc 65.4		32 <b>Ge</b> Germanium 72.6		34 <b>Se</b> Selenium 79.0		36 <b>Kr</b> Krypton 83.8		
3 <b>Li</b> Lithium 6.9	12 <b>Mg</b> Magnesium 24.3	21 <b>Sc</b> Scandium 45.0		23 <b>V</b> Vanadium 50.9		25 <b>Mn</b> Manganese 54.9		27 <b>Co</b> Cobalt 58.9		29 <b>Cu</b> Copper 63.5		31 <b>Ga</b> Gallium 69.7		33 <b>As</b> Arsenic 74.9		35 <b>Br</b> Bromine 79.9		37 <b>Rb</b> Rubidium 85.5	
11 <b>Na</b> Sodium 23.0	20 <b>Ca</b> Calcium 40.1		22 <b>Ti</b> Titanium 47.9		24 <b>Cr</b> Chromium 52.0		26 <b>Fe</b> Iron 55.8		28 <b>Ni</b> Nickel 58.7		30 <b>Zn</b> Zinc 65.4		32 <b>Ge</b> Germanium 72.6		34 <b>Se</b> Selenium 79.0		36 <b>Kr</b> Krypton 83.8		
19 <b>K</b> Potassium 39.1	18 <b>Ar</b> Argon 39.9		21 <b>Sc</b> Scandium 45.0		23 <b>V</b> Vanadium 50.9		25 <b>Mn</b> Manganese 54.9		27 <b>Co</b> Cobalt 58.9		29 <b>Cu</b> Copper 63.5		31 <b>Ga</b> Gallium 69.7		33 <b>As</b> Arsenic 74.9		35 <b>Br</b> Bromine 79.9		
37 <b>Rb</b> Rubidium 85.5	38 <b>Sr</b> Strontium 87.6		40 <b>Zr</b> Zirconium 91.2		42 <b>Mo</b> Molybdenum 95.9		44 <b>Ru</b> Ruthenium 101.1		46 <b>Pd</b> Palladium 106.4		48 <b>Cd</b> Cadmium 112.4		50 <b>Sn</b> Tin 118.7		52 <b>Te</b> Tellurium 127.6		54 <b>Xe</b> Xenon 131.3		
55 <b>Cs</b> Cesium 132.9	56 <b>Ba</b> Barium 137.3		72 <b>Hf</b> Hafnium 178.5		74 <b>W</b> Tungsten 183.8		76 <b>Os</b> Osmium 190.2		78 <b>Pt</b> Platinum 195.1		80 <b>Hg</b> Mercury 200.6		82 <b>Pb</b> Lead 207.2		84 <b>Po</b> Polonium (209)		86 <b>Rn</b> Radon (222)		
87 <b>Fr</b> Francium (223)	88 <b>Ra</b> Radium (226)		104 <b>Rf</b> Rutherfordium (261)		106 <b>Sg</b> Seaborgium (263)		108 <b>Hs</b> Hassium (265)		109 <b>Mt</b> Meitnerium (266)		110 <b>Dt</b> Darmstadtium (262)		112 <b>Cn</b> Copernicium (264)		114 <b>Fl</b> Flerovium (268)		116 <b>Lv</b> Livermorium (260)		
89 <b>Ac</b> Actinium (227)	90 <b>Th</b> Thorium 232.0		91 <b>Pa</b> Protactinium 231.0		92 <b>U</b> Uranium 238.0		93 <b>Np</b> Neptunium (237)		94 <b>Pu</b> Plutonium (244)		95 <b>Am</b> Americium (243)		96 <b>Cm</b> Curium (247)		97 <b>Bk</b> Berkelium (247)		98 <b>Cf</b> Californium (251)		
91 <b>Th</b> Thorium 232.0	90 <b>Th</b> Thorium 232.0		91 <b>Pa</b> Protactinium 231.0		92 <b>U</b> Uranium 238.0		93 <b>Np</b> Neptunium (237)		94 <b>Pu</b> Plutonium (244)		95 <b>Am</b> Americium (243)		96 <b>Cm</b> Curium (247)		97 <b>Bk</b> Berkelium (247)		98 <b>Cf</b> Californium (251)		
93 <b>Pa</b> Protactinium 231.0	91 <b>Pa</b> Protactinium 231.0		92 <b>U</b> Uranium 238.0		93 <b>Np</b> Neptunium (237)		94 <b>Pu</b> Plutonium (244)		95 <b>Am</b> Americium (243)		96 <b>Cm</b> Curium (247)		97 <b>Bk</b> Berkelium (247)		98 <b>Cf</b> Californium (251)		99 <b>Es</b> Einsteinium (252)		
95 <b>Am</b> Americium (243)	93 <b>Np</b> Neptunium (237)		94 <b>Pu</b> Plutonium (244)		95 <b>Am</b> Americium (243)		96 <b>Cm</b> Curium (247)		97 <b>Bk</b> Berkelium (247)		98 <b>Cf</b> Californium (251)		99 <b>Es</b> Einsteinium (252)		100 <b>Fm</b> Fermium (257)		101 <b>Md</b> Mendelevium (258)		
97 <b>Bk</b> Berkelium (247)	95 <b>Am</b> Americium (243)		96 <b>Cm</b> Curium (247)		97 <b>Bk</b> Berkelium (247)		98 <b>Cf</b> Californium (251)		99 <b>Es</b> Einsteinium (252)		100 <b>Fm</b> Fermium (257)		101 <b>Md</b> Mendelevium (258)		102 <b>No</b> Nobelium (259)		103 <b>Lr</b> Lawrencium (262)		
99 <b>Es</b> Einsteinium (252)	97 <b>Bk</b> Berkelium (247)		98 <b>Cf</b> Californium (251)		99 <b>Es</b> Einsteinium (252)		100 <b>Fm</b> Fermium (257)		101 <b>Md</b> Mendelevium (258)		102 <b>No</b> Nobelium (259)		103 <b>Lr</b> Lawrencium (262)		104 <b>Rg</b> Roentgenium (261)		105 <b>Og</b> Oganesson (264)		
101 <b>Md</b> Mendelevium (258)	99 <b>Es</b> Einsteinium (252)		100 <b>Fm</b> Fermium (257)		101 <b>Md</b> Mendelevium (258)		102 <b>No</b> Nobelium (259)		103 <b>Lr</b> Lawrencium (262)		104 <b>Rg</b> Roentgenium (261)		105 <b>Og</b> Oganesson (264)		106 <b>Uu</b> Ununhexium (262)		107 <b>Uub</b> Ununheptium (263)		
103 <b>Lr</b> Lawrencium (262)	101 <b>Md</b> Mendelevium (258)		102 <b>No</b> Nobelium (259)		103 <b>Lr</b> Lawrencium (262)		104 <b>Rg</b> Roentgenium (261)		105 <b>Og</b> Oganesson (264)		106 <b>Uu</b> Ununhexium (262)		107 <b>Uub</b> Ununheptium (263)		108 <b>Uuo</b> Ununoctium (264)		109 <b>Uuq</b> Ununquadium (265)		
105 <b>Og</b> Oganesson (264)	103 <b>Lr</b> Lawrencium (262)		104 <b>Rg</b> Roentgenium (261)		105 <b>Og</b> Oganesson (264)		106 <b>Uu</b> Ununhexium (262)		107 <b>Uub</b> Ununheptium (263)		108 <b>Uuo</b> Ununoctium (264)		109 <b>Uuq</b> Ununquadium (265)		110 <b>Uuq</b> Ununquadium (265)		111 <b>Uuq</b> Ununquadium (265)		
107 <b>Uub</b> Ununheptium (263)	105 <b>Og</b> Oganesson (264)		106 <b>Uu</b> Ununhexium (262)		107 <b>Uub</b> Ununheptium (263)		108 <b>Uuo</b> Ununoctium (264)		109 <b>Uuq</b> Ununquadium (265)		110 <b>Uuq</b> Ununquadium (265)		111 <b>Uuq</b> Ununquadium (265)		112 <b>Uuq</b> Ununquadium (265)		113 <b>Uuq</b> Ununquadium (265)		
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125 <b>Uuq</b> Ununquadium (265)	123 <b>Uuq</b> Ununquadium (265)		124 <b>Uuq</b> Ununquadium (265)		125 <b>Uuq</b> Ununquadium (265)		126 <b>Uuq</b> Ununquadium (265)		127 <b>Uuq</b> Ununquadium (265)		128 <b>Uuq</b> Ununquadium (265)		129 <b>Uuq</b> Ununquadium (265)		130 <b>Uuq</b> Ununquadium (265)		131 <b>Uuq</b> Ununquadium (265)		
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143 <b>Uuq</b> Ununquadium (265)	141 <b>Uuq</b> Ununquadium (265)		142 <b>Uuq</b> Ununquadium (265)		143 <b>Uuq</b> Ununquadium (265)		144 <b>Uuq</b> Ununquadium (265)		145 <b>Uuq</b> Ununquadium (265)		146 <b>Uuq</b> Ununquadium (265)		147 <b>Uuq</b> Ununquadium (265)		148 <b>Uuq</b> Ununquadium (265)		149 <b>Uuq</b> Ununquadium (265)		
145 <b>Uuq</b> Ununquadium (265)	143 <b>Uuq</b> Ununquadium (265)		144 <b>Uuq</b> Ununquadium (265)		145 <b>Uuq</b> Ununquadium (265)		146 <b>Uuq</b> Ununquadium (265)		147 <b>Uuq</b> Ununquadium (265)		148 <b>Uuq</b> Ununquadium (265)		149 <b>Uuq</b> Ununquadium (265)		150 <b>Uuq</b> Ununquadium (265)		151 <b>Uuq</b> Ununquadium (265)		
147 <b>Uuq</b> Ununquadium (265)	145 <b>Uuq</b> Ununquadium (265)		146 <b>Uuq</b> Ununquadium (265)		147 <b>Uuq</b> Ununquadium (265)		148 <b>Uuq</b> Ununquadium (265)		149 <b>Uuq</b> 										

# ATOMIC MASSES OF THE ELEMENTS

*Based on mass of C<sup>12</sup> at 12.00.*

*Values in parentheses are the mass number of the most stable or best known isotopes for elements that do not occur naturally.*

Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)
Aluminum	Al	13	27.0
Americium	Am	95	(243)
Antimony	Sb	51	121.8
Argon	Ar	18	39.9
Arsenic	As	33	74.9
Astatine	At	85	(210)
Barium	Ba	56	137.3
Berkelium	Bk	97	(247)
Beryllium	Be	4	9.0
Bismuth	Bi	83	209.0
Boron	B	5	10.8
Bromine	Br	35	79.9
Cadmium	Cd	48	112.4
Calcium	Ca	20	40.1
Californium	Cf	98	(251)
Carbon	C	6	12.0
Cerium	Ce	58	140.1
Cesium	Cs	55	132.9
Chlorine	Cl	17	35.5
Chromium	Cr	24	52.0
Cobalt	Co	27	58.9
Copper	Cu	29	63.5
Curium	Cm	96	(247)
Dubnium	Db	105	(262)
Dysprosium	Dy	66	162.5
Einsteinium	Es	99	(252)
Erbium	Er	68	167.3
Europium	Eu	63	152.0
Fermium	Fm	100	(257)
Fluorine	F	9	19.0
Francium	Fr	87	(223)
Gadolinium	Gd	64	157.3
Gallium	Ga	31	69.7
Germanium	Ge	32	72.6
Gold	Au	79	197.0
Hafnium	Hf	72	178.5
Helium	He	2	4.0
Holmium	Ho	67	164.9
Hydrogen	H	1	1.0
Indium	In	49	114.8
Iodine	I	53	126.9
Iridium	Ir	77	192.2
Iron	Fe	26	55.8
Krypton	Kr	36	83.8
Lanthanum	La	57	138.9
Lawrencium	Lr	103	(262)
Lead	Pb	82	207.2
Lithium	Li	3	6.9
Lutetium	Lu	71	175.0
Magnesium	Mg	12	24.3
Manganese	Mn	25	54.9
Mendelevium	Md	101	(258)

Element	Symbol	Atomic Number	Atomic Mass
Mercury	Hg	80	200.6
Molybdenum	Mo	42	95.9
Neodymium	Nd	60	144.2
Neon	Ne	10	20.2
Neptunium	Np	93	(237)
Nickel	Ni	28	58.7
Niobium	Nb	41	92.9
Nitrogen	N	7	14.0
Nobelium	No	102	(259)
Osmium	Os	76	190.2
Oxygen	O	8	16.0
Palladium	Pd	46	106.4
Phosphorus	P	15	31.0
Platinum	Pt	78	195.1
Plutonium	Pu	94	(244)
Polonium	Po	84	(209)
Potassium	K	19	39.1
Praseodymium	Pr	59	140.9
Promethium	Pm	61	(145)
Protactinium	Pa	91	231.0
Radium	Ra	88	(226)
Radon	Rn	86	(222)
Rhenium	Re	75	186.2
Rhodium	Rh	45	102.9
Rubidium	Rb	37	85.5
Ruthenium	Ru	44	101.1
Rutherfordium	Rf	104	(261)
Samarium	Sm	62	150.4
Scandium	Sc	21	45.0
Selenium	Se	34	79.0
Silicon	Si	14	28.1
Silver	Ag	47	107.9
Sodium	Na	11	23.0
Strontium	Sr	38	87.6
Sulphur	S	16	32.1
Tantalum	Ta	73	180.9
Technetium	Tc	43	(98)
Tellurium	Te	52	127.6
Terbium	Tb	65	158.9
Thallium	Tl	81	204.4
Thorium	Th	90	232.0
Thulium	Tm	69	168.9
Tin	Sn	50	118.7
Titanium	Ti	22	47.9
Tungsten	W	74	183.8
Uranium	U	92	238.0
Vanadium	V	23	50.9
Xenon	Xe	54	131.3
Ytterbium	Yb	70	173.0
Yttrium	Y	39	88.9
Zinc	Zn	30	65.4
Zirconium	Zr	40	91.2

## NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

\* *Aqueous solutions are readily oxidized by air.*

\*\* *Not stable in aqueous solutions.*

<b>Positive Ions (Cations)</b>			
$\text{Al}^{3+}$	Aluminum	$\text{Pb}^{4+}$	Lead(IV), plumbic
$\text{NH}_4^+$	Ammonium	$\text{Li}^+$	Lithium
$\text{Ba}^{2+}$	Barium	$\text{Mg}^{2+}$	Magnesium
$\text{Ca}^{2+}$	Calcium	$\text{Mn}^{2+}$	Manganese(II), manganous
$\text{Cr}^{2+}$	Chromium(II), chromous	$\text{Mn}^{4+}$	Manganese(IV)
$\text{Cr}^{3+}$	Chromium(III), chromic	$\text{Hg}_2^{2+}$	Mercury(I)*, mercurous
$\text{Cu}^+$	Copper(I)*, cuprous	$\text{Hg}^{2+}$	Mercury(II), mercuric
$\text{Cu}^{2+}$	Copper(II), cupric	$\text{K}^+$	Potassium
$\text{H}^+$	Hydrogen	$\text{Ag}^+$	Silver
$\text{H}_3\text{O}^+$	Hydronium	$\text{Na}^+$	Sodium
$\text{Fe}^{2+}$	Iron(II)*, ferrous	$\text{Sn}^{2+}$	Tin(II)*, stannous
$\text{Fe}^{3+}$	Iron(III), ferric	$\text{Sn}^{4+}$	Tin(IV), stannic
$\text{Pb}^{2+}$	Lead(II), plumbous	$\text{Zn}^{2+}$	Zinc

<b>Negative Ions (Anions)</b>			
$\text{Br}^-$	Bromide	$\text{OH}^-$	Hydroxide
$\text{CO}_3^{2-}$	Carbonate	$\text{ClO}^-$	Hypochlorite
$\text{ClO}_3^-$	Chlorate	$\text{I}^-$	Iodide
$\text{Cl}^-$	Chloride	$\text{HPO}_4^{2-}$	Monohydrogen phosphate
$\text{ClO}_2^-$	Chlorite	$\text{NO}_3^-$	Nitrate
$\text{CrO}_4^{2-}$	Chromate	$\text{NO}_2^-$	Nitrite
$\text{CN}^-$	Cyanide	$\text{C}_2\text{O}_4^{2-}$	Oxalate
$\text{Cr}_2\text{O}_7^{2-}$	Dichromate	$\text{O}^{2-}$	Oxide**
$\text{H}_2\text{PO}_4^-$	Dihydrogen phosphate	$\text{ClO}_4^-$	Perchlorate
$\text{CH}_3\text{COO}^-$	Ethanoate, acetate	$\text{MnO}_4^-$	Permanganate
$\text{F}^-$	Fluoride	$\text{PO}_4^{3-}$	Phosphate
$\text{HCO}_3^-$	Hydrogen carbonate, bicarbonate	$\text{SO}_4^{2-}$	Sulphate
$\text{HC}_2\text{O}_4^-$	Hydrogen oxalate, binoxalate	$\text{S}^{2-}$	Sulphide
$\text{HSO}_4^-$	Hydrogen sulphate, bisulphate	$\text{SO}_3^{2-}$	Sulphite
$\text{HS}^-$	Hydrogen sulphide, bisulphide	$\text{SCN}^-$	Thiocyanate
$\text{HSO}_3^-$	Hydrogen sulphite, bisulphite		

## SOLUBILITY OF COMMON COMPOUNDS IN WATER

*The term soluble here means > 0.1 mol/L at 25°C.*

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li <sup>+</sup> , Na <sup>+</sup> , K <sup>+</sup> , Rb <sup>+</sup> , Cs <sup>+</sup> , Fr <sup>+</sup>	Soluble
All	Hydrogen ion: H <sup>+</sup>	Soluble
All	Ammonium ion: NH <sub>4</sub> <sup>+</sup>	Soluble
Nitrate, NO <sub>3</sub> <sup>-</sup>	All	Soluble
Chloride, Cl <sup>-</sup> or Bromide, Br <sup>-</sup> or Iodide, I <sup>-</sup>	All others	Soluble
	Ag <sup>+</sup> , Pb <sup>2+</sup> , Cu <sup>+</sup>	Low Solubility
Sulphate, SO <sub>4</sub> <sup>2-</sup>	All others	Soluble
	Ag <sup>+</sup> , Ca <sup>2+</sup> , Sr <sup>2+</sup> , Ba <sup>2+</sup> , Pb <sup>2+</sup>	Low Solubility
Sulphide, S <sup>2-</sup>	Alkali ions, H <sup>+</sup> , NH <sub>4</sub> <sup>+</sup> , Be <sup>2+</sup> , Mg <sup>2+</sup> , Ca <sup>2+</sup> , Sr <sup>2+</sup> , Ba <sup>2+</sup>	Soluble
	All others	Low Solubility
Hydroxide, OH <sup>-</sup>	Alkali ions, H <sup>+</sup> , NH <sub>4</sub> <sup>+</sup> , Sr <sup>2+</sup>	Soluble
	All others	Low Solubility
Phosphate, PO <sub>4</sub> <sup>3-</sup> or Carbonate, CO <sub>3</sub> <sup>2-</sup> or Sulphite, SO <sub>3</sub> <sup>2-</sup>	Alkali ions, H <sup>+</sup> , NH <sub>4</sub> <sup>+</sup>	Soluble
	All others	Low Solubility

## SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	$K_{sp}$
Barium carbonate	BaCO <sub>3</sub>	$2.6 \times 10^{-9}$
Barium chromate	BaCrO <sub>4</sub>	$1.2 \times 10^{-10}$
Barium sulphate	BaSO <sub>4</sub>	$1.1 \times 10^{-10}$
Calcium carbonate	CaCO <sub>3</sub>	$5.0 \times 10^{-9}$
Calcium oxalate	CaC <sub>2</sub> O <sub>4</sub>	$2.3 \times 10^{-9}$
Calcium sulphate	CaSO <sub>4</sub>	$7.1 \times 10^{-5}$
Copper(I) iodide	CuI	$1.3 \times 10^{-12}$
Copper(II) iodate	Cu(IO <sub>3</sub> ) <sub>2</sub>	$6.9 \times 10^{-8}$
Copper(II) sulphide	CuS	$6.0 \times 10^{-37}$
Iron(II) hydroxide	Fe(OH) <sub>2</sub>	$4.9 \times 10^{-17}$
Iron(II) sulphide	FeS	$6.0 \times 10^{-19}$
Iron(III) hydroxide	Fe(OH) <sub>3</sub>	$2.6 \times 10^{-39}$
Lead(II) bromide	PbBr <sub>2</sub>	$6.6 \times 10^{-6}$
Lead(II) chloride	PbCl <sub>2</sub>	$1.2 \times 10^{-5}$
Lead(II) iodate	Pb(IO <sub>3</sub> ) <sub>2</sub>	$3.7 \times 10^{-13}$
Lead(II) iodide	PbI <sub>2</sub>	$8.5 \times 10^{-9}$
Lead(II) sulphate	PbSO <sub>4</sub>	$1.8 \times 10^{-8}$
Magnesium carbonate	MgCO <sub>3</sub>	$6.8 \times 10^{-6}$
Magnesium hydroxide	Mg(OH) <sub>2</sub>	$5.6 \times 10^{-12}$
Silver bromate	AgBrO <sub>3</sub>	$5.3 \times 10^{-5}$
Silver bromide	AgBr	$5.4 \times 10^{-13}$
Silver carbonate	Ag <sub>2</sub> CO <sub>3</sub>	$8.5 \times 10^{-12}$
Silver chloride	AgCl	$1.8 \times 10^{-10}$
Silver chromate	Ag <sub>2</sub> CrO <sub>4</sub>	$1.1 \times 10^{-12}$
Silver iodate	AgIO <sub>3</sub>	$3.2 \times 10^{-8}$
Silver iodide	AgI	$8.5 \times 10^{-17}$
Strontium carbonate	SrCO <sub>3</sub>	$5.6 \times 10^{-10}$
Strontium fluoride	SrF <sub>2</sub>	$4.3 \times 10^{-9}$
Strontium sulphate	SrSO <sub>4</sub>	$3.4 \times 10^{-7}$
Zinc sulphide	ZnS	$2.0 \times 10^{-25}$

# RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

*in aqueous solution at room temperature.*

Name of Acid	Acid	Base	$K_a$
Perchloric	$\text{HClO}_4$	$\rightarrow \text{H}^+ + \text{ClO}_4^-$	very large
Hydriodic	$\text{HI}$	$\rightarrow \text{H}^+ + \text{I}^-$	very large
Hydrobromic	$\text{HBr}$	$\rightarrow \text{H}^+ + \text{Br}^-$	very large
Hydrochloric	$\text{HCl}$	$\rightarrow \text{H}^+ + \text{Cl}^-$	very large
Nitric	$\text{HNO}_3$	$\rightarrow \text{H}^+ + \text{NO}_3^-$	very large
Sulphuric	$\text{H}_2\text{SO}_4$	$\rightarrow \text{H}^+ + \text{HSO}_4^-$	very large
Hydronium Ion	$\text{H}_3\text{O}^+$	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{O}$	1.0
Iodic	$\text{HIO}_3$	$\rightleftharpoons \text{H}^+ + \text{IO}_3^-$	$1.7 \times 10^{-1}$
Oxalic	$\text{H}_2\text{C}_2\text{O}_4$	$\rightleftharpoons \text{H}^+ + \text{HC}_2\text{O}_4^-$	$5.9 \times 10^{-2}$
Sulphurous ( $\text{SO}_2 + \text{H}_2\text{O}$ )	$\text{H}_2\text{SO}_3$	$\rightleftharpoons \text{H}^+ + \text{HSO}_3^-$	$1.5 \times 10^{-2}$
Hydrogen sulphate ion	$\text{HSO}_4^-$	$\rightleftharpoons \text{H}^+ + \text{SO}_4^{2-}$	$1.2 \times 10^{-2}$
Phosphoric	$\text{H}_3\text{PO}_4$	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{PO}_4^-$	$7.5 \times 10^{-3}$
Hexaaquoiron ion, iron(III) ion	$\text{Fe}(\text{H}_2\text{O})_6^{3+}$	$\rightleftharpoons \text{H}^+ + \text{Fe}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	$6.0 \times 10^{-3}$
Citric	$\text{H}_3\text{C}_6\text{H}_5\text{O}_7$	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{C}_6\text{H}_5\text{O}_7^-$	$7.1 \times 10^{-4}$
Nitrous	$\text{HNO}_2$	$\rightleftharpoons \text{H}^+ + \text{NO}_2^-$	$4.6 \times 10^{-4}$
Hydrofluoric	$\text{HF}$	$\rightleftharpoons \text{H}^+ + \text{F}^-$	$3.5 \times 10^{-4}$
Methanoic, formic	$\text{HCOOH}$	$\rightleftharpoons \text{H}^+ + \text{HCOO}^-$	$1.8 \times 10^{-4}$
Hexaaquochromium ion, chromium(III) ion	$\text{Cr}(\text{H}_2\text{O})_6^{3+}$	$\rightleftharpoons \text{H}^+ + \text{Cr}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	$1.5 \times 10^{-4}$
Benzoic	$\text{C}_6\text{H}_5\text{COOH}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{COO}^-$	$6.5 \times 10^{-5}$
Hydrogen oxalate ion	$\text{HC}_2\text{O}_4^-$	$\rightleftharpoons \text{H}^+ + \text{C}_2\text{O}_4^{2-}$	$6.4 \times 10^{-5}$
Ethanoic, acetic	$\text{CH}_3\text{COOH}$	$\rightleftharpoons \text{H}^+ + \text{CH}_3\text{COO}^-$	$1.8 \times 10^{-5}$
Dihydrogen citrate ion	$\text{H}_2\text{C}_6\text{H}_5\text{O}_7^-$	$\rightleftharpoons \text{H}^+ + \text{HC}_6\text{H}_5\text{O}_7^{2-}$	$1.7 \times 10^{-5}$
Hexaaquoaluminum ion, aluminum ion	$\text{Al}(\text{H}_2\text{O})_6^{3+}$	$\rightleftharpoons \text{H}^+ + \text{Al}(\text{H}_2\text{O})_5(\text{OH})^{2+}$	$1.4 \times 10^{-5}$
Carbonic ( $\text{CO}_2 + \text{H}_2\text{O}$ )	$\text{H}_2\text{CO}_3$	$\rightleftharpoons \text{H}^+ + \text{HCO}_3^-$	$4.3 \times 10^{-7}$
Monohydrogen citrate ion	$\text{HC}_6\text{H}_5\text{O}_7^{2-}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{O}_7^{3-}$	$4.1 \times 10^{-7}$
Hydrogen sulphite ion	$\text{HSO}_3^-$	$\rightleftharpoons \text{H}^+ + \text{SO}_3^{2-}$	$1.0 \times 10^{-7}$
Hydrogen sulphide	$\text{H}_2\text{S}$	$\rightleftharpoons \text{H}^+ + \text{HS}^-$	$9.1 \times 10^{-8}$
Dihydrogen phosphate ion	$\text{H}_2\text{PO}_4^-$	$\rightleftharpoons \text{H}^+ + \text{HPO}_4^{2-}$	$6.2 \times 10^{-8}$
Boric	$\text{H}_3\text{BO}_3$	$\rightleftharpoons \text{H}^+ + \text{H}_2\text{BO}_3^-$	$7.3 \times 10^{-10}$
Ammonium ion	$\text{NH}_4^+$	$\rightleftharpoons \text{H}^+ + \text{NH}_3$	$5.6 \times 10^{-10}$
Hydrocyanic	$\text{HCN}$	$\rightleftharpoons \text{H}^+ + \text{CN}^-$	$4.9 \times 10^{-10}$
Phenol	$\text{C}_6\text{H}_5\text{OH}$	$\rightleftharpoons \text{H}^+ + \text{C}_6\text{H}_5\text{O}^-$	$1.3 \times 10^{-10}$
Hydrogen carbonate ion	$\text{HCO}_3^-$	$\rightleftharpoons \text{H}^+ + \text{CO}_3^{2-}$	$5.6 \times 10^{-11}$
Hydrogen peroxide	$\text{H}_2\text{O}_2$	$\rightleftharpoons \text{H}^+ + \text{HO}_2^-$	$2.4 \times 10^{-12}$
Monohydrogen phosphate ion	$\text{HPO}_4^{2-}$	$\rightleftharpoons \text{H}^+ + \text{PO}_4^{3-}$	$2.2 \times 10^{-13}$
Water	$\text{H}_2\text{O}$	$\rightleftharpoons \text{H}^+ + \text{OH}^-$	$1.0 \times 10^{-14}$
Hydroxide ion	$\text{OH}^-$	$\leftarrow \text{H}^+ + \text{O}^{2-}$	very small
Ammonia	$\text{NH}_3$	$\leftarrow \text{H}^+ + \text{NH}_2^-$	very small

STRONG

STRENGTH OF ACID

WEAK

WEAK

STRENGTH OF BASE

STRONG

## ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

# STANDARD REDUCTION POTENTIALS OF HALF-CELLS

*Ionic concentrations are at 1M in water at 25°C.*

**STRENGTH OF OXIDIZING AGENT**

**STRENGTH OF REDUCING AGENT**

Oxidizing Agents	Reducing Agents	E° (Volts)
$F_{2(g)} + 2e^-$	$\rightleftharpoons 2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	$\rightleftharpoons 2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	$\rightleftharpoons 2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	$\rightleftharpoons Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	$\rightleftharpoons Au_{(s)}$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	$\rightleftharpoons \frac{1}{2}Br_{2(l)} + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	$\rightleftharpoons Cl^- + 4H_2O$	+1.39
$Cl_{2(g)} + 2e^-$	$\rightleftharpoons 2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	$\rightleftharpoons 2Cr^{3+} + 7H_2O$	+1.23
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$	$\rightleftharpoons H_2O$	+1.23
$MnO_{2(s)} + 4H^+ + 2e^-$	$\rightleftharpoons Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	$\rightleftharpoons \frac{1}{2}I_{2(s)} + 3H_2O$	+1.20
$Br_{2(l)} + 2e^-$	$\rightleftharpoons 2Br^-$	+1.09
$AuCl_4^- + 3e^-$	$\rightleftharpoons Au_{(s)} + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	$\rightleftharpoons NO_{(g)} + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	$\rightleftharpoons Hg_{(l)}$	+0.85
$\frac{1}{2}O_{2(g)} + 2H^+(10^{-7}M) + 2e^-$	$\rightleftharpoons H_2O$	+0.82
$2NO_3^- + 4H^+ + 2e^-$	$\rightleftharpoons N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	$\rightleftharpoons Ag_{(s)}$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^-$	$\rightleftharpoons Hg_{(l)}$	+0.80
$Fe^{3+} + e^-$	$\rightleftharpoons Fe^{2+}$	+0.77
$O_{2(g)} + 2H^+ + 2e^-$	$\rightleftharpoons H_2O_2$	+0.70
$MnO_4^- + 2H_2O + 3e^-$	$\rightleftharpoons MnO_{2(s)} + 4OH^-$	+0.60
$I_{2(s)} + 2e^-$	$\rightleftharpoons 2I^-$	+0.54
$Cu^+ + e^-$	$\rightleftharpoons Cu_{(s)}$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	$\rightleftharpoons S_{(s)} + 3H_2O$	+0.45
$Cu^{2+} + 2e^-$	$\rightleftharpoons Cu_{(s)}$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	$\rightleftharpoons H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	$\rightleftharpoons Cu^+$	+0.15
$Sn^{4+} + 2e^-$	$\rightleftharpoons Sn^{2+}$	+0.15
$S_{(s)} + 2H^+ + 2e^-$	$\rightleftharpoons H_2S_{(g)}$	+0.14
$2H^+ + 2e^-$	$\rightleftharpoons H_{2(g)}$	+0.00
$Pb^{2+} + 2e^-$	$\rightleftharpoons Pb_{(s)}$	-0.13
$Sn^{2+} + 2e^-$	$\rightleftharpoons Sn_{(s)}$	-0.14
$Ni^{2+} + 2e^-$	$\rightleftharpoons Ni_{(s)}$	-0.26
$H_3PO_4 + 2H^+ + 2e^-$	$\rightleftharpoons H_3PO_3 + H_2O$	-0.28
$Co^{2+} + 2e^-$	$\rightleftharpoons Co_{(s)}$	-0.28
$Se_{(s)} + 2H^+ + 2e^-$	$\rightleftharpoons H_2Se$	-0.40
$Cr^{3+} + e^-$	$\rightleftharpoons Cr^{2+}$	-0.41
$2H_2O + 2e^-$	$\rightleftharpoons H_2 + 2OH^-(10^{-7}M)$	-0.41
$Fe^{2+} + 2e^-$	$\rightleftharpoons Fe_{(s)}$	-0.45
$Ag_2S_{(s)} + 2e^-$	$\rightleftharpoons 2Ag_{(s)} + S^{2-}$	-0.69
$Cr^{3+} + 3e^-$	$\rightleftharpoons Cr_{(s)}$	-0.74
$Zn^{2+} + 2e^-$	$\rightleftharpoons Zn_{(s)}$	-0.76
$Te_{(s)} + 2H^+ + 2e^-$	$\rightleftharpoons H_2Te$	-0.79
$2H_2O + 2e^-$	$\rightleftharpoons H_{2(g)} + 2OH^-$	-0.83
$Mn^{2+} + 2e^-$	$\rightleftharpoons Mn_{(s)}$	-1.19
$Al^{3+} + 3e^-$	$\rightleftharpoons Al_{(s)}$	-1.66
$Mg^{2+} + 2e^-$	$\rightleftharpoons Mg_{(s)}$	-2.37
$Na^+ + e^-$	$\rightleftharpoons Na_{(s)}$	-2.71
$Ca^{2+} + 2e^-$	$\rightleftharpoons Ca_{(s)}$	-2.87
$Sr^{2+} + 2e^-$	$\rightleftharpoons Sr_{(s)}$	-2.89
$Ba^{2+} + 2e^-$	$\rightleftharpoons Ba_{(s)}$	-2.91
$K^+ + e^-$	$\rightleftharpoons K_{(s)}$	-2.93
$Rb^+ + e^-$	$\rightleftharpoons Rb_{(s)}$	-2.98
$Cs^+ + e^-$	$\rightleftharpoons Cs_{(s)}$	-3.03
$Li^+ + e^-$	$\rightleftharpoons Li_{(s)}$	-3.04

Overpotential Effect

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