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BRITISH COLUMBIA

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

1. This examination consists of **two** parts:

	Value	Suggested Time
PART A: 48 multiple-choice questions	60	70
PART B: 13 written-response questions	40	50
Total:	**100 marks**	**120 minutes**

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. $Pb_{(s)} + CuCl_{2(aq)} \rightarrow Cu_{(s)} + PbCl_{2(aq)}$

   B. $HCl_{(aq)} + NaOH_{(aq)} \rightarrow H_2O_{(\ell)} + NaCl_{(aq)}$

   C. $H_2SO_{4(aq)} + Ba(OH)_{2(aq)} \rightarrow 2H_2O_{(\ell)} + BaSO_{4(s)}$

   D. $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$

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

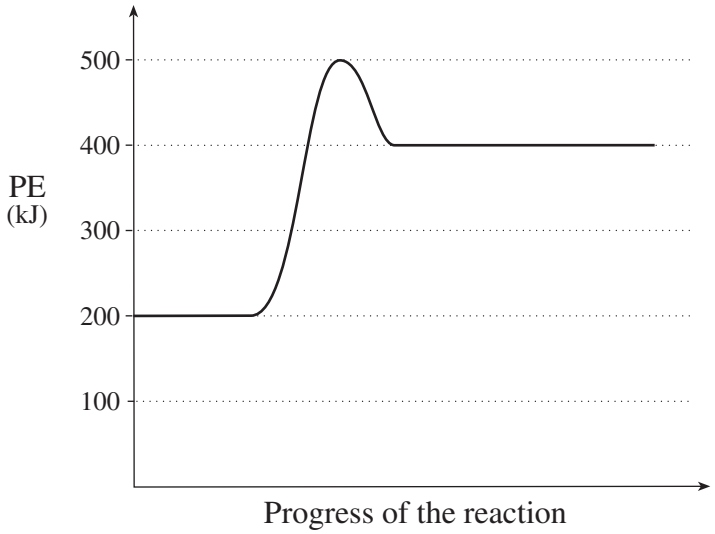
   A. catalyst
   B. temperature
   C. surface area
   D. concentration

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

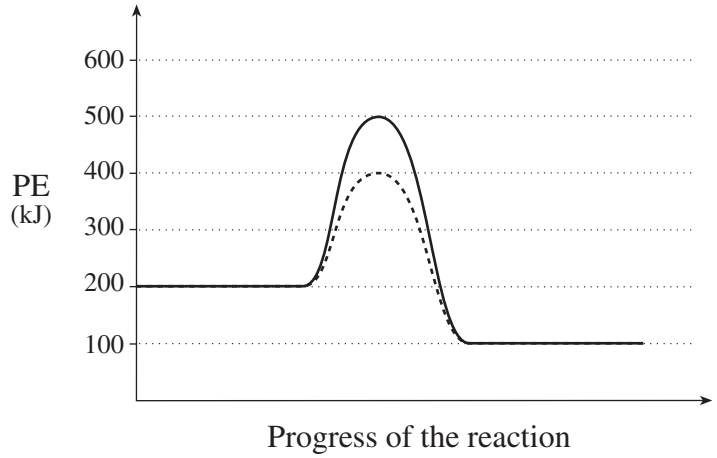
5. Consider the following reaction mechanism: **(1 mark)**

Step 1	$2NO_2 \rightarrow NO_3 + NO$
Step 2	$NO_3 + CO \rightarrow NO_2 + CO_2$

Identify a product in the overall reaction.

A. CO
B. CO_2
C. NO_2
D. NO_3

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)	ΔH (kJ)
A.	uncatalyzed	300	−100
B.	catalyzed	300	−100
C.	uncatalyzed	400	+100
D.	catalyzed	400	+100

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

$$2HBr_{(g)} \rightleftarrows H_{2(g)} + Br_{2(g)}$$

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

OVER

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

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} + \text{energy}$$

8. Which of the following two stresses will each cause the system to shift to the right? **(1 mark)**

   A. decrease temperature, decrease $[O_2]$

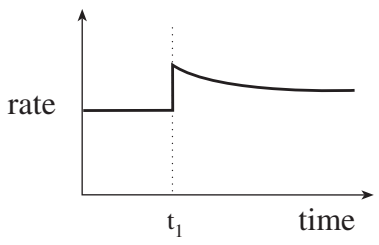
   B. increase temperature, increase $[SO_3]$

   C. increase temperature, decrease $[SO_3]$

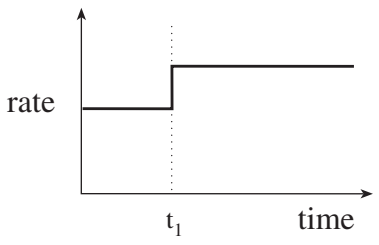
   D. decrease temperature, increase $[SO_2]$

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)**

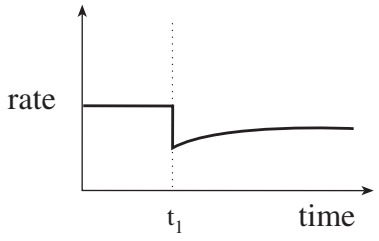
A.



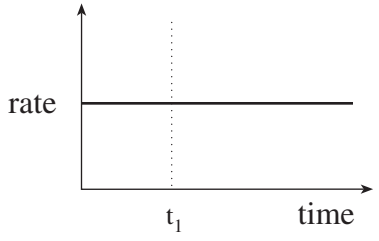
B.



C.



D.



10. Consider the following: **(2 marks)**

$$2N_{2(g)} + O_{2(g)} + \text{energy} \overset{?}{\rightleftarrows} 2N_2O_{(g)}$$

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)**

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

Initially, some HI is placed into a 1.0 L container. At equilibrium there is 0.010 mol H_2, 0.010 mol 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

OVER

12. What is the equilibrium expression for the following system? **(1 mark)**

$$4Fe_{(s)} + 3O_{2(g)} \rightleftarrows 2Fe_2O_{3(s)}$$

A. $K_{eq} = [O_2]^3$

B. $K_{eq} = \dfrac{1}{[O_2]^3}$

C. $K_{eq} = \dfrac{[Fe_2O_3]^2}{[Fe]^4[O_2]^3}$

D. $K_{eq} = \dfrac{[2Fe_2O_3]}{[4Fe][3O_2]}$

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)**

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$$

An equilibrium mixture contains 4.0×10^{-2} mol N_2O_4 and 1.5×10^{-2} mol NO_2 in a 1.0 L flask. What is the value of K_{eq} ?

A. 5.6×10^{-3}

B. 3.8×10^{-1}

C. 7.5×10^{-1}

D. 1.8×10^{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 $3.0\,\text{L}$ solution of $BaCl_2$ has a chloride ion concentration of $0.20\,\text{M}$. 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. CaS
B. CuS
C. FeS
D. MgS

18. What is the formula equation for the reaction that occurs when equal volumes of $0.20\,\text{M}$ K_3PO_4 and $0.20\,\text{M}$ $ZnCl_2$ are mixed together? **(1 mark)**

A. $K^+_{(aq)} + Cl^-_{(aq)} \rightarrow KCl_{(s)}$

B. $3Zn^{2+}_{(aq)} + 2PO_4{}^{3-}_{(aq)} \rightarrow Zn_3(PO_4)_{2(s)}$

C. $2K_3PO_{4(aq)} + 3ZnCl_{2(aq)} \rightarrow Zn_3(PO_4)_{2(s)} + 6KCl_{(aq)}$

D. $2K_3PO_{4(aq)} + 3\,ZnCl_{2(aq)} \rightarrow 3Zn_3(PO_4)_{2(aq)} + 6KCl_{(s)}$

OVER

19. Which of the following could be added to a sample of hard water to remove both $0.2\,\text{M}\ \text{Ca}^{2+}$ and $0.2\,\text{M}\ \text{Mg}^{2+}$? **(1 mark)**

A. $0.2\,\text{M}\ \text{S}^{2-}$

B. $0.2\,\text{M}\ \text{Cl}^{-}$

C. $0.2\,\text{M}\ \text{OH}^{-}$

D. $0.2\,\text{M}\ \text{SO}_4^{2-}$

20. The K_{sp} expression for a saturated solution of Ag_2SO_3 is **(1 mark)**

A. $\text{K}_{sp} = \left[2\text{Ag}^{+}\right]\left[\text{SO}_3^{2-}\right]$

B. $\text{K}_{sp} = \left[\text{Ag}^{+}\right]^2\left[\text{SO}_3^{2-}\right]$

C. $\text{K}_{sp} = \left[\text{Ag}_2^{2+}\right]\left[\text{SO}_3^{2-}\right]$

D. $\text{K}_{sp} = \left[2\text{Ag}^{+}\right]^2\left[\text{SO}_3^{2-}\right]$

21. The solubility of CaF_2 is $3.3 \times 10^{-4}\,\text{M}$. Determine the K_{sp} value of CaF_2 . **(2 marks)**

A. 3.6×10^{-11}

B. 1.4×10^{-10}

C. 1.1×10^{-7}

D. 3.3×10^{-4}

22. What is the maximum $\left[\text{Ag}^{+}\right]$ that can exist in a solution of $0.010\,\text{M}\ \text{NaIO}_3$? **(1 mark)**

A. 3.2×10^{-10} M

B. 3.2×10^{-8} M

C. 3.2×10^{-6} M

D. 1.8×10^{-4} M

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

A. releases $H^+_{(aq)}$

B. releases $OH^-_{(aq)}$

C. accepts a proton

D. donates a proton

24. The conjugate acid of $HAsO_4^{2-}$ is **(1 mark)**

A. AsO_4^{3-}

B. AsO_4^{2-}

C. $H_2AsO_4^-$

D. $H_2AsO_4^{2-}$

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 H_2SO_3

OVER

26. Consider the equilibrium: **(2 marks)**

$$C_6H_5COOH + NO_2^- \rightleftarrows HNO_2 + C_6H_5COO^-$$

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

	Stronger Acid	Side Favoured
A.	HNO_2	reactants
B.	HNO_2	products
C.	C_6H_5COOH	reactants
D.	C_6H_5COOH	products

27. Which of the following represents the equilibrium expression for the ionization of water? **(1 mark)**

A. $K_w = \left[H_3O^+\right]\left[OH^-\right]$

B. $K_w = \dfrac{1}{\left[H_3O^+\right]\left[OH^-\right]}$

C. $K_w = \left[H_3O^+\right] + \left[OH^-\right]$

D. $K_w = \dfrac{\left[H_3O^+\right]\left[OH^-\right]}{\left[H_2O\right]}$

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 NH_4NO_3 is represented by **(1 mark)**

A. $NH_4NO_{3(s)} \rightarrow {NH_4}^+_{(aq)} + {NO_3}^-_{(aq)}$

B. ${NH_4}^+_{(aq)} + {NO_3}^-_{(aq)} \rightarrow NH_4NO_{3(s)}$

C. ${NH_4}^+_{(aq)} + H_2O_{(\ell)} \rightarrow {H_3O}^+_{(aq)} + NH_{3(aq)}$

D. ${NO_3}^-_{(aq)} + H_2O_{(\ell)} \rightarrow HNO_{3(aq)} + {OH}^-_{(aq)}$

31. A solution of $Al(NO_3)_3$ will be **(1 mark)**

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

OVER

32. Consider the following equilibrium for the chemical indicator phenol red, $HInd$, at a $pH = 7.3$ (orange). **(2 marks)**

$$\underset{\text{yellow}}{HInd} + H_2O \rightleftarrows H_3O^+ + \underset{\text{red}}{Ind^-}$$

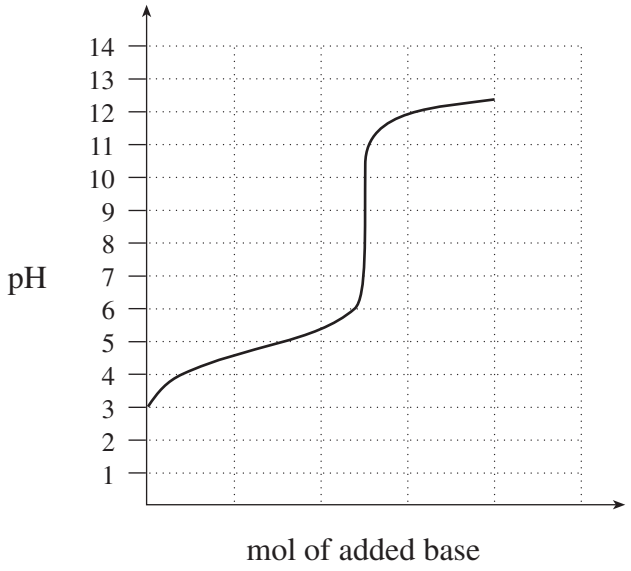
When some $NaOH$ is added, what stress is imposed on the equilibrium and what colour change occurs?

	Stress	Indicator Colour Change
A.	increased $\left[H_3O^+\right]$	turns red
B.	decreased $\left[H_3O^+\right]$	turns red
C.	increased $\left[H_3O^+\right]$	turns yellow
D.	decreased $\left[H_3O^+\right]$	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 $0.300\,M\ HNO_3$ needed to completely neutralize $25.0\,mL$ of $0.250\,M\ Sr(OH)_2$. **(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 $NaNO_3$
D. NH_3 and NH_4Cl

OVER

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

A. $2CaO_{(s)} \rightarrow Ca_2O_{2(aq)}$
B. $2CaO_{(s)} \rightarrow 2Ca_{(aq)} + O_{2(aq)}$
C. $CaO_{(s)} + H_2O_{(\ell)} \rightarrow Ca(OH)_{2(aq)}$
D. $CaO_{(s)} + H_2O_{(\ell)} \rightarrow CaOH_{(aq)} + O_{2(aq)}$

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

A. H_2S
B. H_2O
C. H_2Se
D. H_2Te

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

$$H_2SeO_3 \rightarrow Se$$

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 Br_2 but not with I_2 ? **(1 mark)**

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

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

$$Sn^{4+} + 2Cl^- \rightarrow Sn^{2+} + Cl_2$$

What is true for this reaction?

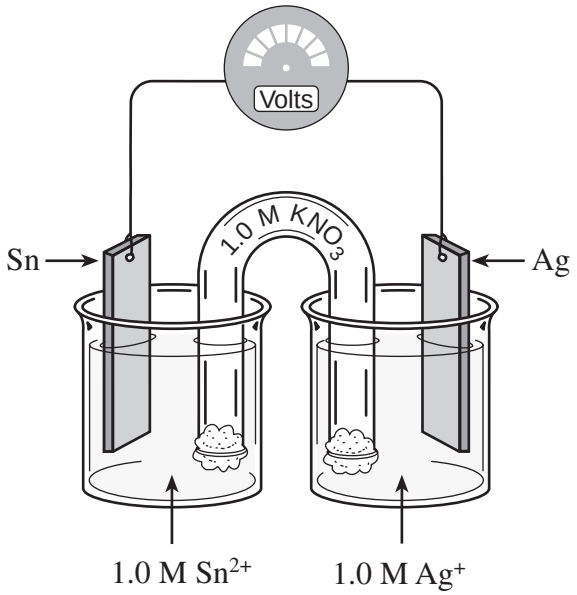
A. $E^\circ_{cell} = +1.51\,V$ and it is spontaneous.
B. $E^\circ_{cell} = +1.21\,V$ and it is spontaneous.
C. $E^\circ_{cell} = -1.21\,V$ and it is non-spontaneous.
D. $E^\circ_{cell} = -1.51\,V$ and it is non-spontaneous.

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.

OVER

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 $E°$ for the cell? **(1 mark)**

A. −0.94 V
B. −0.66 V
C. +0.66 V
D. +0.94 V

46. Consider the following equation: **(1 mark)**

$$Cd^{2+} + 2I^- \rightleftarrows Cd + I_2 \qquad E^\circ_{cell} = -0.94\,V$$

What is E° for the reduction of Cd^{2+} ?

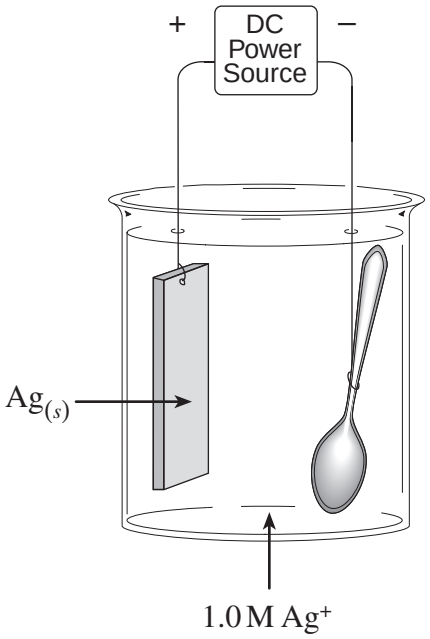
A. $-0.40\,V$
B. $-0.14\,V$
C. $+0.14\,V$
D. $+0.40\,V$

47. Which of the following describes an operating electrochemical cell? **(2 marks)**

	E°	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. $Ag \rightarrow Ag^+ + e^-$

B. $Ag^+ + e^- \rightarrow Ag$

C. $Cu \rightarrow Cu^{2+} + 2e^-$

D. $Cu^{2+} + 2e^- \rightarrow Cu$

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)**

$$2Al_{(s)} + 6HCl_{(aq)} \rightarrow 2AlCl_{3(aq)} + 3H_{2(g)}$$

A 10.0 g sample of Al reacts completely in excess HCl in 300.0 s.
What is the rate of production of H_2 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)**

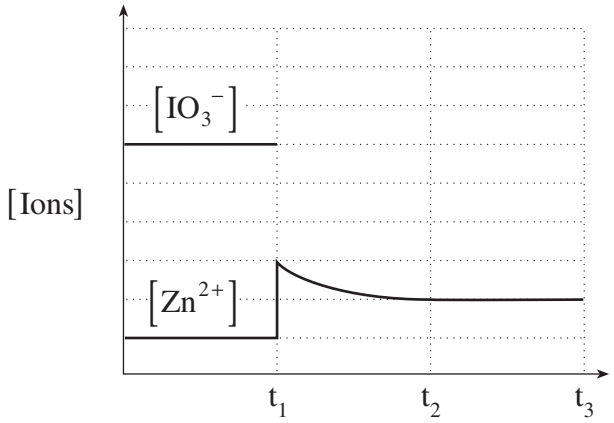
$$H_{2(g)} + Br_{2(g)} \rightleftarrows 2HBr_{(g)} \qquad K_{eq} = 12.0$$

Initially, $0.080\,\text{mol}$ H_2 and $0.080\,\text{mol}$ Br_2 are placed into a $4.00\,\text{L}$ container. What is the $[HBr]$ at equilibrium?

OVER

5. Consider the following equilibrium and accompanying graph:

$$Zn(IO_3)_{2(s)} \rightleftarrows Zn^{2+}_{(aq)} + 2IO_3{}^-_{(aq)}$$



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

b) Complete the above graph from t_1 to t_3 for the $[IO_3^-]$. **(2 marks)**

6. Calculate the solubility of $SrSO_4$ in grams per litre. **(3 marks)**

7. The cyanide ion, CN^-, is a Brønsted-Lowry base.

a) Define *Brønsted-Lowry base*. **(1 mark)**

_____

_____

b) Write the equation representing the reaction of 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)**

OVER

9. Calculate the pH of $1.50\,M\ NH_3$. **(5 marks)**

10. Consider the following buffer equilibrium: **(3 marks)**

$$\underset{\text{high concentration}}{HF_{(aq)}} + H_2O_{(\ell)} \rightleftarrows \underset{\text{low concentration}}{H_3O^+_{(aq)}} + \underset{\text{high concentration}}{F^-_{(aq)}}$$

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)**

$$Ag + NO_3^- \rightarrow Ag^+ + NO \qquad \text{(acidic)}$$

OVER

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 $HNO_{3(aq)}$ and another sample of copper is placed in $HCl_{(aq)}$.

a) In which acid does the copper react? **(½ mark)**

_____

b) Calculate E° for the reaction that occurs. **(1½ marks)**

END OF EXAMINATION

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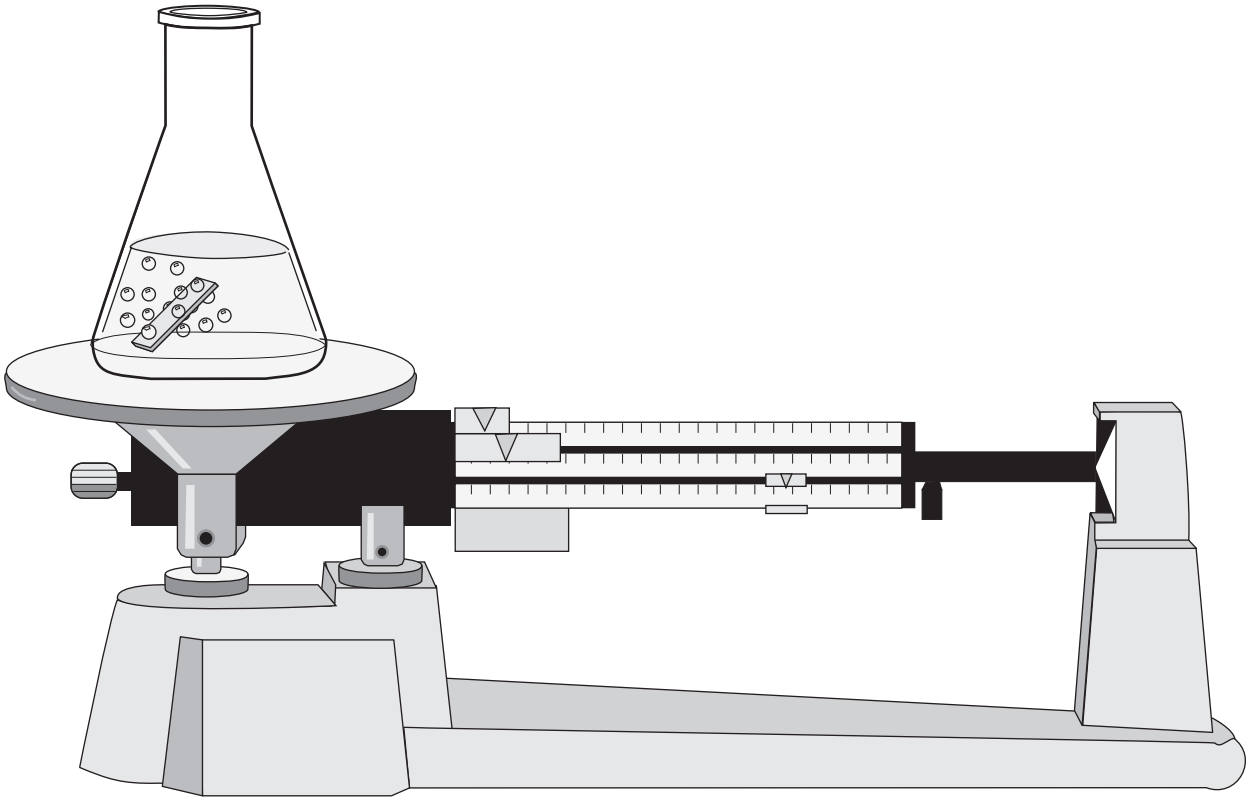
Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised January 2000

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80th 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 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

14 — Atomic Number
Si — Symbol
Silicon — Name
28.1 — Atomic Mass

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce Cerium 140.1	**Pr** Praseodymium 140.9	**Nd** Neodymium 144.2	**Pm** Promethium (145)	**Sm** Samarium 150.4	**Eu** Europium 152.0	**Gd** Gadolinium 157.3	**Tb** Terbium 158.9	**Dy** Dysprosium 162.5	**Ho** Holmium 164.9	**Er** Erbium 167.3	**Tm** Thulium 168.9	**Yb** Ytterbium 173.0	**Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

ATOMIC MASSES OF THE ELEMENTS

Based on mass of C^{12} 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)
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.*

Positive Ions (Cations)			
Al^{3+}	Aluminum	Pb^{4+}	Lead(IV), plumbic
NH_4^+	Ammonium	Li^+	Lithium
Ba^{2+}	Barium	Mg^{2+}	Magnesium
Ca^{2+}	Calcium	Mn^{2+}	Manganese(II), manganous
Cr^{2+}	Chromium(II), chromous	Mn^{4+}	Manganese(IV)
Cr^{3+}	Chromium(III), chromic	Hg_2^{2+}	Mercury(I)*, mercurous
Cu^+	Copper(I)*, cuprous	Hg^{2+}	Mercury(II), mercuric
Cu^{2+}	Copper(II), cupric	K^+	Potassium
H^+	Hydrogen	Ag^+	Silver
H_3O^+	Hydronium	Na^+	Sodium
Fe^{2+}	Iron(II)*, ferrous	Sn^{2+}	Tin(II)*, stannous
Fe^{3+}	Iron(III), ferric	Sn^{4+}	Tin(IV), stannic
Pb^{2+}	Lead(II), plumbous	Zn^{2+}	Zinc

Negative Ions (Anions)			
Br^-	Bromide	OH^-	Hydroxide
CO_3^{2-}	Carbonate	ClO^-	Hypochlorite
ClO_3^-	Chlorate	I^-	Iodide
Cl^-	Chloride	HPO_4^{2-}	Monohydrogen phosphate
ClO_2^-	Chlorite	NO_3^-	Nitrate
CrO_4^{2-}	Chromate	NO_2^-	Nitrite
CN^-	Cyanide	$C_2O_4^{2-}$	Oxalate
$Cr_2O_7^{2-}$	Dichromate	O^{2-}	Oxide**
$H_2PO_4^-$	Dihydrogen phosphate	ClO_4^-	Perchlorate
CH_3COO^-	Ethanoate, acetate	MnO_4^-	Permanganate
F^-	Fluoride	PO_4^{3-}	Phosphate
HCO_3^-	Hydrogen carbonate, bicarbonate	SO_4^{2-}	Sulphate
$HC_2O_4^-$	Hydrogen oxalate, binoxalate	S^{2-}	Sulphide
HSO_4^-	Hydrogen sulphate, bisulphate	SO_3^{2-}	Sulphite
HS^-	Hydrogen sulphide, bisulphide	SCN^-	Thiocyanate
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^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	$BaCO_3$	2.6×10^{-9}
Barium chromate	$BaCrO_4$	1.2×10^{-10}
Barium sulphate	$BaSO_4$	1.1×10^{-10}
Calcium carbonate	$CaCO_3$	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	$CaSO_4$	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$Cu(IO_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	$Fe(OH)_2$	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.6×10^{-39}
Lead(II) bromide	$PbBr_2$	6.6×10^{-6}
Lead(II) chloride	$PbCl_2$	1.2×10^{-5}
Lead(II) iodate	$Pb(IO_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	$PbSO_4$	1.8×10^{-8}
Magnesium carbonate	$MgCO_3$	6.8×10^{-6}
Magnesium hydroxide	$Mg(OH)_2$	5.6×10^{-12}
Silver bromate	$AgBrO_3$	5.3×10^{-5}
Silver bromide	$AgBr$	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	$AgIO_3$	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	$SrCO_3$	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	$SrSO_4$	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

STRENGTH OF ACID: STRONG (top) → WEAK (bottom)

STRENGTH OF BASE: WEAK (top) → STRONG (bottom)

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small

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.

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

Overpotential Effect

Overpotential Effect

STRONG

STRENGTH OF OXIDIZING AGENT

WEAK

WEAK

STRENGTH OF REDUCING AGENT

STRONG