MINISTRY USE ONLY

MINISTRY USE ONLY

Place Personal Education Number (PEN) here.

Place Personal Education Number (PEN) here.

MINISTRY USE ONLY

BRITISH COLUMBIA

Chemistry 12

JANUARY 2001

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. ☐ . ☐

(5)

Question 6:

6. ☐ . ☐

(2)

Question 2:

2. ☐ . ☐

(5)

Question 7:

7. ☐ . ☐

(6)

Question 3:

3. ☐ . ☐

(2)

Question 8:

8. ☐ . ☐

(4)

Question 4:

4. ☐ . ☐

(2)

Question 9:

9. ☐ . ☐

(5)

Question 5:

5. ☐ . ☐

(5)

Question 10:

10. ☐ . ☐

(4)

CHEMISTRY 12

JANUARY 2001

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: 10 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.

THIS PAGE INTENTIONALLY BLANK

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 units could be used to express reaction rate? **(1 mark)**

   A. mL/s
   B. mL/g
   C. g/mL
   D. mL/mol

2. Consider the reaction: **(1 mark)**

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

   The rate of production of $ZnCl_2$, can be increased by

   A. decreasing the $[HCl]$.
   B. increasing the temperature.
   C. increasing the volume of H_2.
   D. decreasing the surface area of Zn.

3. The statement, *the minimum energy needed to achieve a successful collision,* defines **(1 mark)**

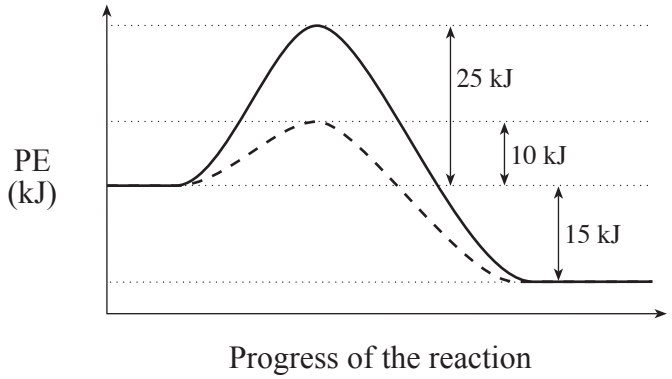
   A. entropy.
   B. activation energy.
   C. the ΔH of reaction.
   D. the activated complex.

OVER

4. As an activated complex changes to products, **(1 mark)**

A. potential energy changes to kinetic energy.
B. kinetic energy changes to potential energy.
C. kinetic energy changes to activation energy.
D. potential energy changes to activation energy.

5. Consider the following PE diagram for an uncatalysed and a catalyzed reaction: **(2 marks)**



Which of the following describes the forward catalyzed reaction?

	Activation Energy (kJ)	ΔH (kJ)
A.	10	–15
B.	10	15
C.	25	–15
D.	25	15

6. A substance that increases the rate of a reaction without appearing in the equation for the overall reaction is a(n) **(1 mark)**

A. product.
B. catalyst.
C. reactant.
D. intermediate.

7. All chemical equilibriums have: **(1 mark)**

I.	rates that are continuing to change
II.	an equilibrium constant expression
III.	equal concentrations of products and reactants

A. II only
B. III only
C. I and II only
D. I and III only

8. From the following, select the situation where both enthalpy and entropy favour the reaction toward products: **(1 mark)**

	Enthalpy	Entropy
A.	increasing	increasing
B.	increasing	decreasing
C.	decreasing	decreasing
D.	decreasing	increasing

OVER

9. Consider the following equilibrium: **(1 mark)**

$$2NO_{(g)} + Br_{2(g)} \rightleftarrows 2NOBr_{(g)} + \text{energy}$$

The equilibrium will shift to the left as a result of

A. adding a catalyst.

B. adding some $NO_{(g)}$.

C. increasing the volume.

D. decreasing the temperature.

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

$$PCl_{3(g)} + 3NH_{3(g)} \rightleftarrows P(NH_2)_{3(g)} + 3HCl_{(g)}$$

The volume of the equilibrium system is increased and a new equilibrium is established. How have the rates been affected?

	Rate (forward)	Rate (reverse)
A.	increased	decreased
B.	decreased	increased
C.	decreased	decreased
D.	did not change	did not change

11. Starting with equal moles of reactants, which of the following equilibrium systems most favours the reactants? **(1 mark)**

A. $SO_{2(g)} + NO_{2(g)} \rightleftarrows SO_{3(g)} + NO_{(g)}$ $K_{eq} = 3.4$

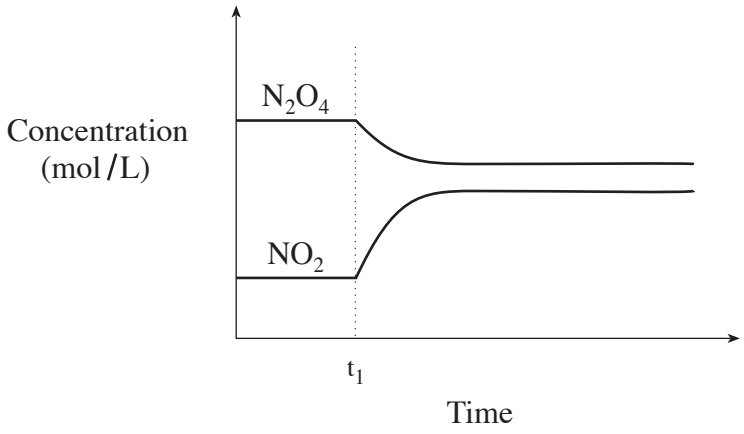
B. $CO_{(g)} + H_2O_{(g)} \rightleftarrows CO_{2(g)} + H_{2(g)}$ $K_{eq} = 31.4$

C. $H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$ $K_{eq} = 10$

D. $N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)}$ $K_{eq} = 1.0 \times 10^{-31}$

12. Consider the following equilibrium reaction: **(2 marks)**

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



At time t_1, heat is applied to the system. Which of the following best describes the equilibrium reaction and the change in K_{eq}?

A. exothermic and K_{eq} increases
B. exothermic and K_{eq} decreases
C. endothermic and K_{eq} increases
D. endothermic and K_{eq} decreases

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

$$PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)} \qquad K_{eq} = 0.45 \text{ at } 227°C$$

Initially, a 1.00 L flask is filled with 0.100 mol PCl_3, 0.100 mol Cl_2, and 0.100 mol PCl_5 at 227°C. Use K_{Trial} to predict the change in $[Cl_2]$ as equilibrium is established.

	K_{Trial}	$[Cl_2]$
A.	$K_{Trial} > K_{eq}$	increases
B.	$K_{Trial} < K_{eq}$	increases
C.	$K_{Trial} > K_{eq}$	decreases
D.	$K_{Trial} < K_{eq}$	decreases

OVER

14. A saturated solution forms when a $0.10\,\text{mol}$ of salt is added to $1.0\,\text{L}$ of water. The salt is **(1 mark)**

A. Li_2S
B. $CuBr_2$
C. $Zn(OH)_2$
D. $(NH_4)_2CO_3$

15. Consider the following equilibrium: **(1 mark)**

$$Ca(OH)_{2(s)} \rightleftarrows Ca^{2+}_{(aq)} + 2\,OH^-_{(aq)}$$

Adding which of the following could cause the equilibrium $\left[Ca^{2+}\right]$ to increase?

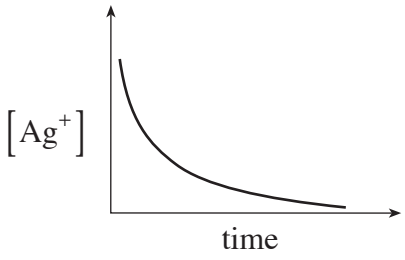
A. $H_2O_{(\ell)}$
B. $HCl_{(aq)}$
C. $KOH_{(s)}$
D. $Ca(OH)_{2(s)}$

16. Consider the following solubility equilibrium: **(1 mark)**

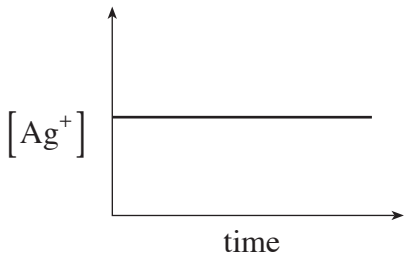
$$AgCl_{(s)} \rightleftarrows Ag^+_{(aq)} + Cl^-_{(aq)}$$

Which of the following graphs represents the $\left[Ag^+\right]$ after equilibrium has been established?

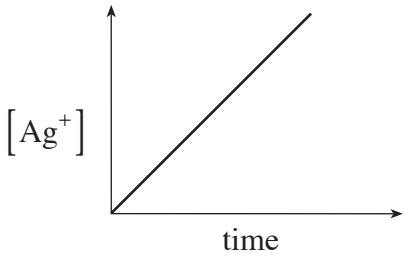
A.



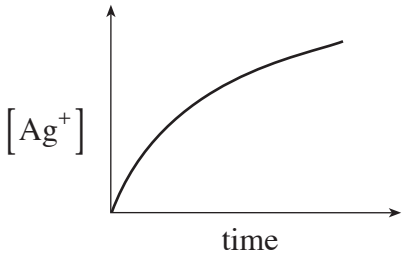
B.



C.



D.



17. The concentrations of the cation and anion in $0.40\,\text{M}\ (NH_4)_2Cr_2O_{7(aq)}$ are **(1 mark)**

	Cation	Anion
A.	0.40 M	0.40 M
B.	0.40 M	0.80 M
C.	0.80 M	0.40 M
D.	0.80 M	0.80 M

18. Which of the following will produce a solution with the highest $[OH^-]$? **(1 mark)**

A. AgOH
B. $Sr(OH)_2$
C. $Fe(OH)_3$
D. $Mg(OH)_2$

19. When equal volumes of $0.20\,\text{M}\ ZnSO_4$ and $0.20\,\text{M}$ SrS are combined **(2 marks)**

A. a precipitate does not form.
B. a precipitate of only ZnS forms.
C. a precipitate of only $SrSO_4$ forms.
D. precipitates of both ZnS and $SrSO_4$ form.

20. What is the concentration of Pb^{2+} in a saturated solution of $Pb(IO_3)_2$? **(2 marks)**

A. 9.0×10^{-5} M
B. 5.7×10^{-5} M
C. 4.5×10^{-5} M
D. 1.1×10^{-4} M

OVER

21. Which of the following tests could be used to distinguish between 1.0 M HCl and 1.0 M NaOH? **(1 mark)**

I.	electrical conductivity
II.	reaction with zinc to produce hydrogen gas
III.	colour of the indicator phenolphthalein

A. III only
B. I and II only
C. II and III only
D. I, II and III

22. An *Arrhenius base* is defined as a compound that **(1 mark)**

A. accepts OH^- in solution.
B. releases OH^- in solution.
C. accepts protons in solution.
D. donates protons in solution.

23. In which one of the following equations are the Brønsted-Lowry acids and bases all correctly identified? **(1 mark)**

	Acid	+	Base	$\rightleftarrows$	Base	+	Acid
A.	H_2O_2	+	SO_3^{2-}	$\rightleftarrows$	HO_2^-	+	HSO_3^-
B.	H_2O_2	+	SO_3^{2-}	$\rightleftarrows$	HSO_3^-	+	HO_2^-
C.	SO_3^{2-}	+	H_2O_2	$\rightleftarrows$	HO_2^-	+	HSO_3^-
D.	SO_3^{2-}	+	H_2O_2	$\rightleftarrows$	HSO_3^-	+	HO_2^-

24. Which of the following statements applies to 1.0 M $NH_{3(aq)}$ but not to 1.0 M $NaOH_{(aq)}$? **(1 mark)**

A. partially ionizes
B. neutralizes an acid
C. has a pH greater than 7
D. turns bromcresol green from yellow to blue

25. In which of the following are reactants favoured? **(1 mark)**

A. $HNO_2 + CN^- \rightleftarrows NO_2^- + HCN$

B. $H_2S + HCO_3^- \rightleftarrows HS^- + H_2CO_3$

C. $H_3PO_4 + NH_3 \rightleftarrows H_2PO_4^- + NH_4^+$

D. $CH_3COOH + PO_4^{3-} \rightleftarrows CH_3COO^- + HPO_4^{2-}$

26. What is the pOH of a solution prepared by adding 0.50 mol of NaOH to prepare 0.50 L of solution? **(2 marks)**

A. 0.00
B. 0.30
C. 14.00
D. 13.70

27. What is the $\left[H_3O^+\right]$ in a solution with a pOH = 5.20? **(2 marks)**

A. 1.4×10^{-14} M
B. 1.6×10^{-9} M
C. 6.3×10^{-6} M
D. 7.1×10^{-1} M

OVER

28. Which of the following solutions will have a pH = 1.00 ? **(1 mark)**

I.	0.10 M HCl
II.	0.10 M HNO_2
III.	0.10 M NaOH

A. I only.
B. III only.
C. I and II only.
D. I, II and III.

29. K_a for the acid $H_2AsO_4^-$ is 5.6×10^{-8}. What is the value of K_b for $HAsO_4^{2-}$? **(1 mark)**

A. 5.6×10^{-22}
B. 3.2×10^{-14}
C. 1.8×10^{-7}
D. 2.4×10^{-4}

30. In a titration, which of the following has a pH = 7.00 at the equivalence point? **(1 mark)**

A. NH_3 and HNO_3
B. KOH and HCN
C. NaOH and HCl
D. $Ca(OH)_2$ and CH_3COOH

31. Which of the following salts dissolves to produce a basic solution? **(1 mark)**

A. KCl
B. NH_4Br
C. $Fe(NO_3)_3$
D. $LiCH_3COO$

32. What colour would 1.0 M HCl be in an indicator mixture consisting of phenol red and thymolphthalein? **(2 marks)**

A. red
B. blue
C. yellow
D. colourless

33. During a titration, what volume of 0.500 M KOH is necessary to completely neutralize 10.0 mL of 2.00 M CH_3COOH ? **(2 marks)**

A. 10.0 mL
B. 20.0 mL
C. 25.0 mL
D. 40.0 mL

34. Which indicator has a $K_a = 1.0 \times 10^{-6}$? **(1 mark)**

A. neutral red
B. thymol blue
C. thymolphthalein
D. chlorophenol red

35. Acid is added to a buffer solution. When equilibrium is reestablished the buffering effect has resulted in $\left[H_3O^+\right]$ **(1 mark)**

A. increasing slightly.
B. decreasing slightly.
C. increasing considerably.
D. decreasing considerably.

36. A buffer solution will form when 0.10 M NaF is mixed with an equal volume of **(1 mark)**

A. 0.10 M HF
B. 0.10 M HCl
C. 0.10 M NaCl
D. 0.10 M NaOH

OVER

37. Which of the following will dissolve in water to produce an acidic solution? **(1 mark)**

A. CO_2
B. CaO
C. MgO
D. Na_2O

38. Which of the following represents a redox reaction? **(1 mark)**

A. $C + O_2 \rightarrow CO_2$
B. $H_2O + SO_2 \rightarrow H_2SO_3$
C. $H_3O^+ + OH^- \rightarrow 2H_2O$
D. $NaCl + AgNO_3 \rightarrow AgCl + NaNO_3$

39. The oxidation number of each chromium atom in $Cr_2O_7^{2-}$ is **(1 mark)**

A. +5
B. +6
C. +7
D. +12

40. List the ions Co^{2+}, Cu^{2+} and Zn^{2+} in order from strongest to weakest oxidizing agents. **(1 mark)**

A. $Zn^{2+} > Co^{2+} > Cu^{2+}$
B. $Co^{2+} > Cu^{2+} > Zn^{2+}$
C. $Cu^{2+} > Zn^{2+} > Co^{2+}$
D. $Cu^{2+} > Co^{2+} > Zn^{2+}$

41. A piece of Cu reacts spontaneously with 1.0 M Pd^{2+} because **(2 marks)**

A. Cu is a weaker reducing agent than Pd and $E° > 0$.
B. Cu is a weaker reducing agent than Pd and $E° < 0$.
C. Cu is a stronger reducing agent than Pd and $E° > 0$.
D. Cu is a stronger reducing agent than Pd and $E° < 0$.

42. Which two species will not react spontaneously at standard conditions? **(1 mark)**

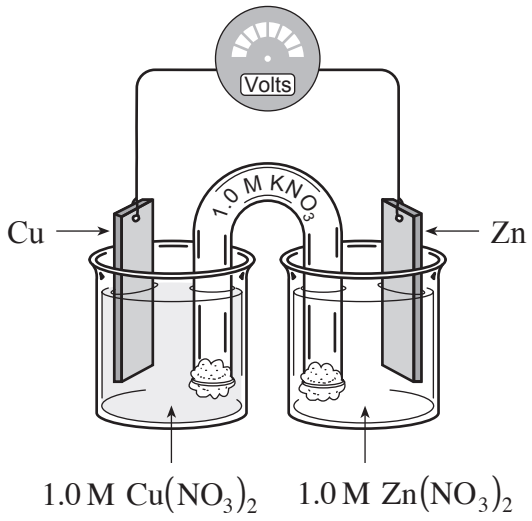
A. Co with Cl_2
B. Cu with Ag^+
C. Ag with Zn^{2+}
D. Mg with Cr^{3+}

43. When a piece of Ag is placed in 1.0 M $NiCl_2$, **(2 marks)**

A. the $\left[Cl^-\right]$ increases.
B. the $\left[Ag^+\right]$ decreases.
C. the $\left[Ni^{2+}\right]$ decreases.
D. no change occurs.

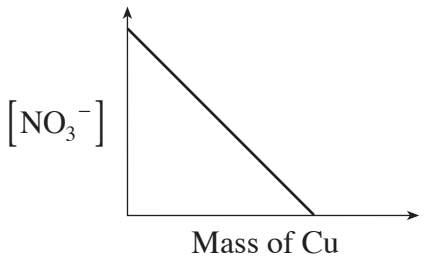
OVER

Use the following cell to answer questions 44 and 45.

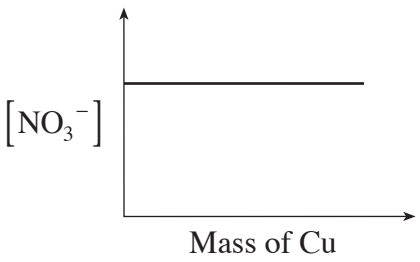


44. Which of the following represents the relationship between $\left[NO_3^-\right]$ and the mass of the Cu electrode in the complete cell as it operates? **(1 mark)**

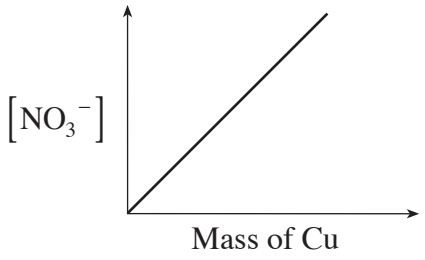
A.



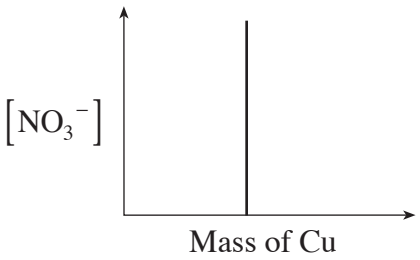
B.



C.



D.



45. The E° for the above cell is **(1 mark)**

A. –1.10 Volts
B. –0.42 Volts
C. +0.42 Volts
D. +1.10 Volts

46. Which of the following is correct for an electrolytic cell? **(1 mark)**

	Value of E°	Type of Reaction
A.	positive	non-spontaneous
B.	positive	spontaneous
C.	negative	spontaneous
D.	negative	non-spontaneous

47. Which of the following will inhibit the corrosion of iron? **(1 mark)**

A. high $\left[O_{2(aq)}\right]$

B. wet conditions

C. coating with zinc

D. increasing the temperature

48. The products of the electrolysis of molten $MgCl_2$ using inert electrodes are **(2 marks)**

A. hydrogen and oxygen.
B. hydrogen and chlorine.
C. magnesium and oxygen.
D. magnesium and chlorine.

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

OVER

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 calculation, full marks will NOT be given for providing only an answer.**

1. Consider the following reaction mechanism for the formation of NO_2.

Step 1	$2NO \rightarrow N_2O_2$
Step 2	_____ $\rightarrow$ _____
Overall	$2NO + O_2 \rightarrow 2NO_2$

a) Complete Step 2. **(2 marks)**

b) Define the term *reaction intermediate*. **(2 marks)**

_____

_____

c) Identify a reaction intermediate in the above mechanism. **(1 mark)**

_____

2. Consider the following equilibrium system:

$$2COF_{2(g)} \rightleftarrows CO_{2(g)} + CF_{4(g)} \qquad K_{eq} = 2.00$$

A $2.00\,L$ container is filled with $0.500\,mol$ of COF_2.
Calculate the $[COF_2]$ at equilibrium. **(5 marks)**

OVER

3. Consider the following equilibrium system:

$$Cu^{2+}_{(aq)} \quad + \quad 4Br^{-}_{(aq)} \quad \rightleftarrows \quad CuBr_4{}^{2-}_{(aq)}$$

blue *colourless* *green*

Cooling the equilibrium changes the colour from green to blue. What effect will the decrease in temperature have on K_{eq} ? Explain, using Le Chatelier's Principle. **(2 marks)**

4. Write the balanced complete ionic equation for the reaction that occurs when $0.20\,M$ of $Ba(NO_3)_2$ is added to an equal volume of $0.20\,M$ Na_2CO_3. **(2 marks)**

5. Calculate the minimum number of moles of $Pb(NO_3)_2$ required to start precipitation in 50.0 mL of 0.15 M ZnI_2 . **(5 marks)**

6. Consider the following Brønsted-Lowry equilibrium:

$$H_2SO_{3(aq)} + HPO_4^{2-}{}_{(aq)} \rightleftarrows H_2PO_4^{-}{}_{(aq)} + HSO_3^{-}{}_{(aq)}$$

a) Identify the two Brønsted-Lowry acids in the above equilibrium. **(1 mark)**

b) Define the term *conjugate acid.* **(1 mark)**

_____

_____

_____

OVER

7. A 250.0 mL sample of HCl with a pH of 2.000 is completely neutralized with 0.200 M NaOH.

a) What volume of NaOH is required to reach the stoichiometric point? **(4 marks)**

b) Write the net ionic equation for the above neutralization reaction. **(1 mark)**

c) If the HCl were titrated with a 0.200 M $NH_{3(aq)}$ instead of 0.200 M NaOH, how would the volume of base required to reach the equivalence point compare with the volume calculated in part a) ? Explain your answer. **(1 mark)**

_____

_____

8. Consider the following equilibrium:

$$\text{energy} + 2H_2O \rightleftarrows H_3O^+ + OH^-$$

a) Explain how pure water can have a $pH = 7.30$. **(2 marks)**

_____

_____

b) Calculate the value of K_w for the sample of water with a $pH = 7.30$. **(2 marks)**

OVER

9. Balance the following redox reaction in basic solution. **(5 marks)**

$$SO_3^{2-} + MnO_4^- \rightarrow SO_4^{2-} + MnO_2 \qquad \text{(basic)}$$

10. Draw and label the parts of an operating electrochemical cell using a zinc anode that will produce an electric current having a voltage of 1.56 V at standard conditions. **(4 marks)**

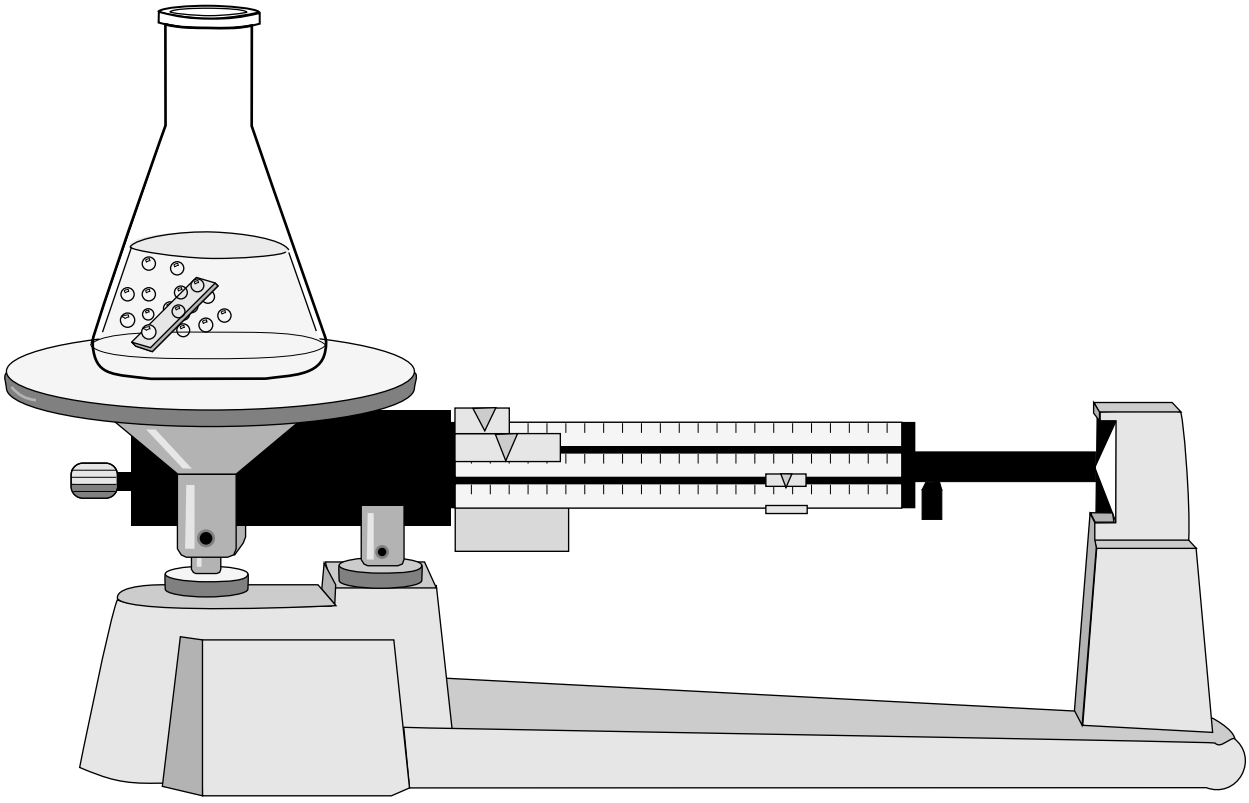
END OF EXAMINATION

THIS PAGE INTENTIONALLY BLANK

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 **Si** Silicon 28.1 — Atomic Number, Symbol, Name, 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