INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

APRIL 1998

PROVINCIAL EXAMINATION

MINISTRY OF EDUCATION, SKILLS AND TRAINING

CHEMISTRY 12

GENERAL INSTRUCTIONS

1. Insert the stickers with your Student I.D. Number (PEN) in the allotted spaces above and on the **back** cover of this booklet. **Under no circumstance is your name or identification, other than your Student I.D. 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. 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.

5. For each of the written-response questions, write your answer in the space provided in this booklet.

6. 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.

7. 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.

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CHEMISTRY 12 PROVINCIAL EXAMINATION

		Value	Suggested Time
1. This examination consists of **two** parts:			
PART A:	48 multiple-choice questions	48	70
PART B:	10 written-response questions	32	50
	Total:	**80 marks**	**120 minutes**

2. Aside from an approved calculator, electronic devices, including dictionaries and pagers, are **not** permitted in the examination room.

3. 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 Brönsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

4. **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. 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 communication between calculators is prohibited during the examination. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

5. The time allotted for this examination is **two hours**.

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PART A: MULTIPLE CHOICE

Value: 48 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.

1. Which of the following units can be used to express the rate of a chemical reaction?

   A. mL/g
   B. mol/L
   C. g/mol
   D. mol/min

2. An increase in temperature increases the rate of a chemical reaction because

   A. the activation energy is lower.
   B. exothermic reactions are always favoured.
   C. a greater fraction of particles have sufficient kinetic energy.
   D. the particles are more likely to have favourable collision geometry.

3. Consider the following reaction:

$$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$$

   To increase the rate of decomposition of $CaCO_3$, one could

   A. add CO_2 .
   B. remove CO_2 .
   C. increase the temperature.
   D. decrease the temperature.

4. A catalyst increases the rate of a chemical reaction by

   A. increasing kinetic energy.
   B. decreasing the heat of reaction.
   C. changing the concentration of reactants.
   D. providing an alternate reaction mechanism.

OVER

5. Consider the following:

I	forward and reverse rates are equal
II	macroscopic properties are constant
III	can be achieved from either direction
IV	concentrations of reactants and products are equal

Which of the above are true for all equilibrium systems?

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

6. In which reaction is the enthalpy of the reactants greater than the enthalpy of the products?

A. $H_2O_{(s)} \rightarrow H_2O_{(\ell)}$
B. $H_2O_{(s)} \rightarrow H_2O_{(g)}$
C. $H_2O_{(\ell)} \rightarrow H_2O_{(s)}$
D. $H_2O_{(\ell)} \rightarrow H_2O_{(g)}$

7. Consider the enthalpy and entropy changes in the following:

$$C_2H_{2(g)} + H_{2(g)} \overset{?}{\rightarrow} C_2H_{4(g)} \qquad \Delta H = -175 \text{ kJ}$$

Which of the following statements is correct?

A. No reaction occurs because both the enthalpy and entropy factors favour the reactants.

B. The reaction goes to completion because both the enthalpy and entropy factors favour the product.

C. The system reaches equilibrium because the enthalpy factor favours the reactants and the entropy factor favours the product.

D. The system reaches equilibrium because the enthalpy factor favours the product and the entropy factor favours the reactants.

8. Consider the following equilibrium:

$$NH_{3(g)} + HCl_{(g)} \rightleftarrows NH_4Cl_{(s)} + \text{energy}$$

Which of the following will result in a decrease in the mass of NH_4Cl?

A. adding NH_3
B. removing HCl
C. decreasing the volume
D. decreasing the temperature

9. Consider the following equilibrium:

$$MgO_{(s)} + H_2O_{(g)} \rightleftarrows Mg(OH)_{2(s)}$$

The equilibrium constant expression is

A. $K_{eq} = [H_2O]$

B. $K_{eq} = \dfrac{1}{[H_2O]}$

C. $K_{eq} = \dfrac{[Mg(OH)_2]}{[MgO]}$

D. $K_{eq} = \dfrac{[Mg(OH)_2]}{[MgO][H_2O]}$

10. Which of the following reactions most favours the reactants?

A. $CH_{4(g)} \rightleftarrows 2H_{2(g)} + C_{(s)}$ $K_{eq} = 1.2 \times 10^{-9}$
B. $SbCl_{5(g)} \rightleftarrows SbCl_{3(g)} + Cl_{2(g)}$ $K_{eq} = 2.5 \times 10^{-2}$
C. $N_2O_{4(g)} \rightleftarrows 2NO_{2(g)}$ $K_{eq} = 4.5 \times 10^{-1}$
D. $C_{(s)} + CO_{2(g)} \rightleftarrows 2CO_{(g)}$ $K_{eq} = 1.4 \times 10^{1}$

OVER

11. Consider the following equilibrium:

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

The pressure on the system is increased by reducing the volume. When comparing the new equilibrium with the original equilibrium,

A. all concentrations remain constant.
B. the concentrations of all species have increased.
C. reactant concentrations have increased while product concentrations have decreased.
D. reactant concentrations have decreased while product concentrations have increased.

12. Consider the following equilibrium:

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

A 1.00 L container is initially filled with 0.200 mol N_2O_4. At equilibrium, 0.160 mol NO_2 are present. What is the equilibrium concentration of N_2O_4?

A. 0.040 mol/L
B. 0.080 mol/L
C. 0.120 mol/L
D. 0.160 mol/L

13. When $Ca(OH)_2$ attains solubility equilibrium, the

A. solution is saturated.
B. pH will be less than 7.
C. Trial K_{sp} is less than the K_{sp}.
D. concentrations of the ions are equal.

14. Which of the following describes the changes in ion concentrations when 1.0 g of solid ZnS is added to a saturated solution of ZnS?

	$[Zn^{2+}]$	$[S^{2-}]$
A.	increases	decreases
B.	decreases	decreases
C.	increases	increases
D.	remains constant	remains constant

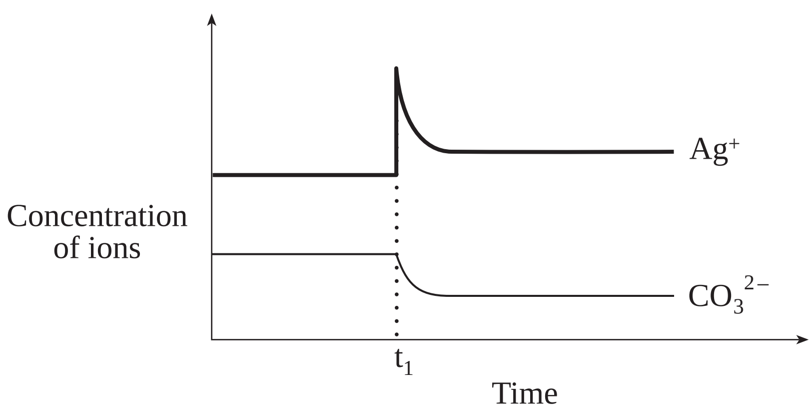
15. When equal volumes of $0.2\ M\ NH_4Cl$ and $0.2\ M\ CuSO_4$ are combined,

A. a precipitate does not form.
B. a precipitate of $CuCl_2$ forms.
C. a precipitate of $(NH_4)_2SO_4$ forms.
D. a precipitate of both $(NH_4)_2SO_4$ and $CuCl_2$ forms.

16. Which of the following anions could be used to separate Pb^{2+} from Ba^{2+} by precipitation?

A. Cl^-
B. OH^-
C. NO_3^-
D. CO_3^{2-}

17. Consider the following graph for a saturated Ag_2CO_3 solution:



What change occurred at time t_1 ?

A. Water was added.
B. $AgNO_{3(s)}$ was added.
C. $Na_2CO_{3(s)}$ was added.
D. The temperature was increased.

OVER

18. The relationship between the solubility of SrF_2 and its K_{sp} is

A. solubility $= \frac{\sqrt[3]{K_{sp}}}{4}$

B. solubility $= \sqrt[3]{\frac{K_{sp}}{2}}$

C. solubility $= \sqrt[3]{\frac{K_{sp}}{4}}$

D. solubility $= \sqrt{K_{sp}}$

19. Which of the following compounds will form a saturated solution with the greatest concentration of Ag^+ ?

A. AgI
B. AgBr
C. $AgIO_3$
D. $AgBrO_3$

20. The net ionic equation for the reaction between $Sr(OH)_2$ and H_2SO_4 is

A. $H^+ + OH^- \rightarrow H_2O$
B. $Sr^{2+} + SO_4{}^{2-} \rightarrow SrSO_4$
C. $Sr(OH)_2 + H_2SO_4 \rightarrow SrSO_4 + 2H_2O$
D. $Sr^{2+} + 2OH^- + 2H^+ + SO_4{}^{2-} \rightarrow SrSO_4 + 2H_2O$

21. Which of the following could act as a Brönsted-Lowry acid, but not as a Brönsted-Lowry base?

A. $NH_{3(aq)}$
B. $H_2O_{(\ell)}$
C. $HClO_{4(aq)}$
D. $HCO_3{}^-{}_{(aq)}$

22. The strength of an acid depends upon its

A. E°
B. pH
C. concentration.
D. degree of ionization.

23. Which of the following 0.1 M solutions will have the greatest electrical conductivity?

A. HNO_2
B. H_2SO_3
C. H_3PO_4
D. C_6H_5OH

24. Consider the following equilibrium:

$$HX^- + HZ^- \rightleftarrows H_2X + Z^{2-}$$

The reactants are favoured. The strongest acid is

A. Z^{2-}
B. HZ^-
C. HX^-
D. H_2X

25. Consider the following equilibrium:

$$2H_2O_{(\ell)} + \text{energy} \rightleftarrows H_3O^+_{(aq)} + OH^-_{(aq)}$$

When the temperature is decreased,

A. $[H_3O^+]$ and K_w both increase.
B. $[H_3O^+]$ and K_w both decrease.
C. $[H_3O^+]$ decreases and K_w increases.
D. $[H_3O^+]$ increases and K_w decreases.

OVER

26. The $\left[OH^{-}\right]$ in 0.050 M HBr equals

A. 1.0×10^{-14} M
B. 2.0×10^{-13} M
C. 5.0×10^{-2} M
D. 2.0×10^{1} M

27. The relationship between pOH and $\left[OH^{-}\right]$ is

A. $-\log pOH = \left[OH^{-}\right]$
B. $pOH = -\log\left[OH^{-}\right]$
C. $\text{antilog } pOH = \left[OH^{-}\right]$
D. $pOH = \text{antilog}\left(-\left[OH^{-}\right]\right)$

28. The pH of a 0.025 M NaOH solution is

A. 0.94
B. 1.60
C. 12.40
D. 13.06

29. Which is the weakest of the following acids?

A. HCN
B. NH_4^{+}
C. HNO_2
D. HNO_3

30. A solution of 0.10 M HSO_3^{-} will be

A. basic because $K_a < K_b$
B. acidic because $K_a < K_b$
C. acidic because $K_a > K_b$
D. neutral because $K_a = K_b$

31. Consider the following equilibrium for the indicator phenol red:

$$\text{HInd} + \text{H}_2\text{O} \rightleftarrows \text{Ind}^- + \text{H}_3\text{O}^+$$

In a solution with a pH of 7.3, the indicator phenol red is

A. red because $[\text{HInd}] < [\text{Ind}^-]$
B. red because $[\text{HInd}] = [\text{Ind}^-]$
C. yellow because $[\text{HInd}] > [\text{Ind}^-]$
D. orange because $[\text{HInd}] = [\text{Ind}^-]$

32. The indicator with $K_a = 4 \times 10^{-8}$ is

A orange IV.
B. neutral red.
C. thymol blue.
D. phenolphthalein.

33. A 25.0 mL sample of H_2SO_4 requires 25.0 mL of 0.100 M KOH for complete neutralization. The initial concentration of the H_2SO_4 is

A. 5.00×10^{-2} M
B. 1.00×10^{-1} M
C. 2.00×10^{-1} M
D. 4.00×10^{-1} M

34. A solution is prepared by adding 10.0 mL of 0.10 M HCl to 25.0 mL of 0.040 M NaOH. The pH of the resulting solution is

A. 1.00
B. 3.00
C. 7.00
D. 12.60

35. A buffer solution can be prepared by combining, in water, equal moles of

A. HF and KF
B. HIO_3 and HI
C. HBr and LiBr
D. $HClO_4$ and NaOH

36. Which of the following oxides will dissolve in water to form an acidic solution?

A. SO_2
B. TiO
C. K_2O
D. MgO

37. Copper has an oxidation number of $+1$ in

A. CuO
B. CuBr
C. CuC_2O_4
D. $Cu(CH_3COO)_2$

38. When ClO_3^- is oxidized, a possible product is

A. Cl^-
B. ClO^-
C. ClO_2^-
D. ClO_4^-

39. Consider the following redox reaction:

$$Pt + 10H^+ + 6Cl^- + 4NO_3^- \rightarrow H_2PtCl_6 + 2N_2O_4 + 4H_2O$$

The reactant that gains electrons is

A. Pt
B. H^+
C. Cl^-
D. NO_3^-

40. Consider the following redox reaction:

$$Zn + 2OH^- + 2H_2O \rightarrow Zn(OH)_4^{2-} + H_2$$

The oxidation half-reaction is

A. $2H_2O \rightarrow H_2 + 2OH^- + 2e^-$
B. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$
C. $Zn + 4OH^- \rightarrow Zn(OH)_4^{2-} + 2e^-$
D. $Zn + 4OH^- + 2e^- \rightarrow Zn(OH)_4^{2-}$

41. In an experiment, Pb^{2+} reacts spontaneously with Rh but not with In. The relative strength of the metals as reducing agents is

A. Rh > Pb > In
B. In > Pb > Rh
C. Pb > Rh > In
D. In > Rh > Pb

42. Consider the following redox reaction:

$$2Fe^{2+} + MnO_2 + 4H^+ \rightleftarrows 2Fe^{3+} + Mn^{2+} + 2H_2O$$

The forward reaction has a

A. positive E° value and is spontaneous.
B. negative E° value and is spontaneous.
C. positive E° value and is nonspontaneous.
D. negative E° value and is nonspontaneous.

OVER

43. When H_2O_2 is added to an acidified MnO_4^- solution, a spontaneous reaction occurs in which a product of the oxidation reaction is

A. O_2
B. H_2O
C. Mn^{2+}
D. MnO_2

44. To determine the $\left[Cr_2O_7^{2-}\right]$ in a redox titration, a suitable reagent is

A. Ni^{2+}
B. Sn^{2+}
C. Zn^{2+}
D. Mg^{2+}

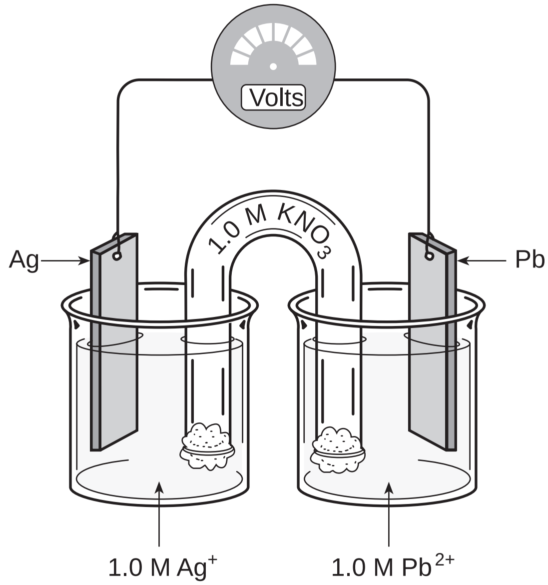
45. In an operating fuel cell, the overall reaction is:

$$2H_2 + O_2 \rightarrow 2H_2O \quad \text{(basic)}$$

The substance being reduced is

A. O_2
B. H_2
C. H_2O
D. KOH

Use the following diagram to answer questions 46 and 47.



46. As the cell operates, which of the following describes the change in each electrode?

	Mass of silver electrode	Mass of lead electrode
A.	increases	decreases
B.	increases	increases
C.	decreases	decreases
D.	decreases	increases

47. The initial voltage of the electrochemical cell above is

A. −0.93 V
B. −0.67 V
C. +0.67 V
D. +0.93 V

48. When molten zinc chloride is electrolyzed, the products are

A. zinc metal and oxygen gas.
B. zinc metal and chlorine gas.
C. hydrogen gas and oxygen gas.
D. hydrogen gas and chlorine gas.

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

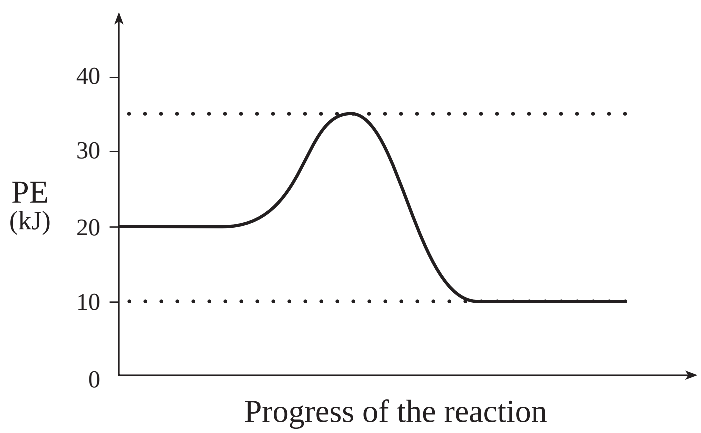
OVER

PART B: WRITTEN RESPONSE

Value: 32 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 potential energy diagram for a reversible reaction:



a) Calculate the activation energy for the forward reaction. **(1 mark)**

b) Calculate ΔH for the forward reaction. **(1 mark)**

c) Calculate the activation energy for the reverse reaction. **(1 mark)**

d) On the diagram above, sketch a curve that could result when a catalyst is added. **(1 mark)**

2. State Le Chatelier's Principle. **(2 marks)**

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3. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 7.1 \times 10^{2}$$

At equilibrium, the $[H_2] = 0.012$ mol/L and $[HI] = 0.40$ mol/L. What is the equilibrium concentration of I_2? **(2 marks)**

OVER

4. Consider the following reaction:

$$Cu_{(s)} + 2AgCH_3COO_{(aq)} \rightarrow Cu(CH_3COO)_{2(aq)} + 2Ag_{(s)}$$

A piece of Cu wire is placed into 1.00 L of a saturated solution of silver acetate, $AgCH_3COO$. When all the Ag^+ has reacted, 2.00 g of Cu has been used.

a) Write the net ionic equation for the reaction between Cu and Ag^+. **(1 mark)**

b) Calculate the K_{sp} of $AgCH_3COO$. **(4 marks)**

5. a) Define the term *weak Brönsted-Lowry base*. **(2 marks)**

b) Give an example of a compound that acts as a weak base. **(1 mark)**

6. Lactic acid, C_2H_5OCOOH, is a weak acid produced by the body. At $25°C$, 0.0100 M C_2H_5OCOOH has a pH of 2.95. Calculate the value of K_a for lactic acid. **(4 marks)**

OVER

7. The salt NaCN dissolves in water and forms a slightly basic solution.

a) Write the dissociation equation for NaCN in water. **(1 mark)**

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

c) Write the K_b expression and calculate its value. **(2 marks)**

8. A redox reaction that occurs in an alkaline dry cell is:

$$Zn + 2MnO_2 \rightarrow Mn_2O_3 + ZnO \quad (\text{basic})$$

Write the balanced equation for the reduction half-reaction occurring in basic solution.
(3 marks)

9. a) Identify a metal that can be used to cathodically protect the iron hull of a ship. **(1 mark)**

b) Explain how the metal you chose prevents the iron from rusting. **(1 mark)**

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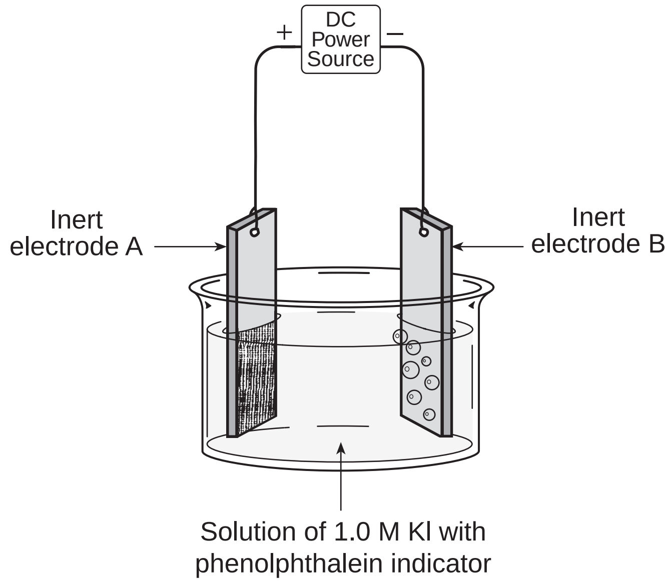
OVER

10. Consider the following cell used for the electrolysis of 1.0 M KI solution containing a few drops of phenolphthalein indicator.



a) Write the equation for the half-reaction taking place at electrode **A**. **(1 mark)**

b) As the cell operates, gas bubbles form and the solution turns pink around electrode **B**. **(2 marks)**

i) Identify the gas that forms.

ii) Explain why the solution turns pink.

END OF EXAMINATION

INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

CHEMISTRY 12

April 1998

Course Code = CH

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CHEMISTRY 12

April 1998

Course Code = CH

Score for Question 1:	Score for Question 8:
1. ______ (4)	8. ______ (3)

Score for Question 2:	Score for Question 9:
2. ______ (2)	9. ______ (2)

Score for Question 3:	Score for Question 10:
3. ______ (2)	10. ______ (3)

Score for Question 4:

4. ______ (5)

Score for Question 5:

5. ______ (3)

Score for Question 6:

6. ______ (4)

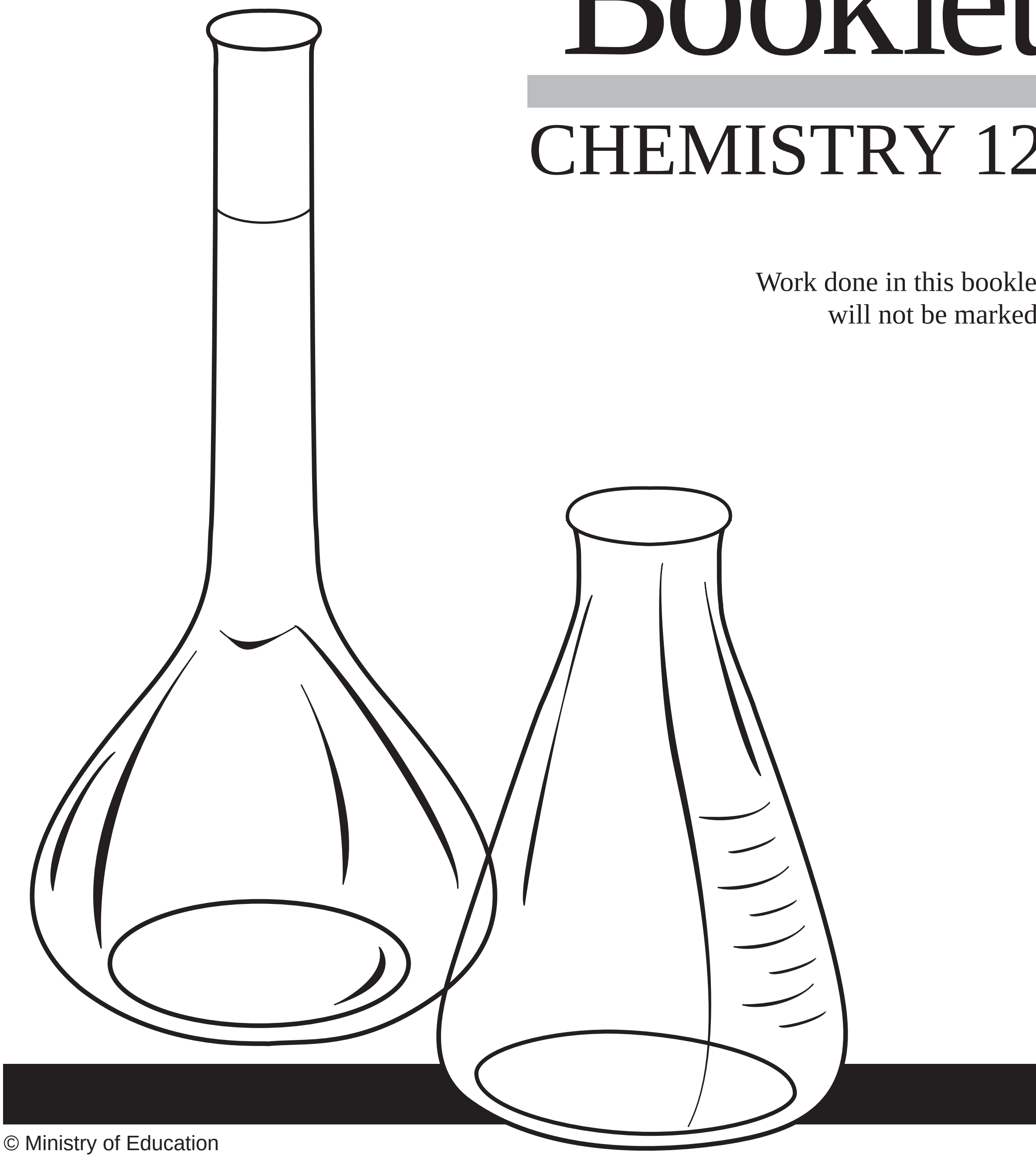
Score for Question 7:

7. ______ (4)

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised November 1994

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 74 edition, CRC Press, Boca Raton, 1993.

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 Ha Hahnium (262)	106 Sg Seaborgium (263)	107 Uns Unnilseptium (262)	108 Uno Unniloctium (265)	109 Une Unnilennium (266)									

Key	
14	Atomic number
Si	Symbol
Silicon	Name
28.1	Atomic mass

58 Ce Cerium 140.1	59 Pr Praseodymium 140.9	60 Nd Neodymium 144.2	61 Pm Promethium (145)	62 Sm Samarium 150.4	63 Eu Europium 152.0	64 Gd Gadolinium 157.3	65 Tb Terbium 158.9	66 Dy Dysprosium 162.5	67 Ho Holmium 164.9	68 Er Erbium 167.3	69 Tm Thulium 168.9	70 Yb Ytterbium 173.0	71 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 of the most stable or best known isotopes for elements which do not occur naturally.

Element	Symbol	Atomic Number	Atomic Mass	Element	Symbol	Atomic Number	Atomic Mass
Actinium	Ac	89	(227)	Mercury	Hg	80	200.6
Aluminum	Al	13	27.0	Molybdenum	Mo	42	95.9
Americium	Am	95	(243)	Neodymium	Nd	60	144.2
Antimony	Sb	51	121.8	Neon	Ne	10	20.2
Argon	Ar	18	39.9	Neptunium	Np	93	(237)
Arsenic	As	33	74.9	Nickel	Ni	28	58.7
Astatine	At	85	(210)	Niobium	Nb	41	92.9
Barium	Ba	56	137.3	Nitrogen	N	7	14.0
Berkelium	Bk	97	(247)	Nobelium	No	102	(259)
Beryllium	Be	4	9.0	Osmium	Os	76	190.2
Bismuth	Bi	83	209.0	Oxygen	O	8	16.0
Boron	B	5	10.8	Palladium	Pd	46	106.4
Bromine	Br	35	79.9	Phosphorus	P	15	31.0
Cadmium	Cd	48	112.4	Platinum	Pt	78	195.1
Calcium	Ca	20	40.1	Plutonium	Pu	94	(244)
Californium	Cf	98	(251)	Polonium	Po	84	(209)
Carbon	C	6	12.0	Potassium	K	19	39.1
Cerium	Ce	58	140.1	Praseodymium	Pr	59	140.9
Cesium	Cs	55	132.9	Promethium	Pm	61	(145)
Chlorine	Cl	17	35.5	Protactinium	Pa	91	231.0
Chromium	Cr	24	52.0	Radium	Ra	88	(226)
Cobalt	Co	27	58.9	Radon	Rn	86	(222)
Copper	Cu	29	63.5	Rhenium	Re	75	186.2
Curium	Cm	96	(247)	Rhodium	Rh	45	102.9
Dysprosium	Dy	66	162.5	Rubidium	Rb	37	85.5
Einsteinium	Es	99	(252)	Ruthenium	Ru	44	101.1
Erbium	Er	68	167.3	Rutherfordium	Rf	104	(261)
Europium	Eu	63	152.0	Samarium	Sm	62	150.4
Fermium	Fm	100	(257)	Scandium	Sc	21	45.0
Fluorine	F	9	19.0	Selenium	Se	34	79.0
Francium	Fr	87	(223)	Silicon	Si	14	28.1
Gadolinium	Gd	64	157.3	Silver	Ag	47	107.9
Gallium	Ga	31	69.7	Sodium	Na	11	23.0
Germanium	Ge	32	72.6	Strontium	Sr	38	87.6
Gold	Au	79	197.0	Sulphur	S	16	32.1
Hafnium	Hf	72	178.5	Tantalum	Ta	73	180.9
Hahnium	Ha	105	(262)	Technetium	Tc	43	(98)
Helium	He	2	4.0	Tellurium	Te	52	127.6
Holmium	Ho	67	164.9	Terbium	Tb	65	158.9
Hydrogen	H	1	1.0	Thallium	Tl	81	204.4
Indium	In	49	114.8	Thorium	Th	90	232.0
Iodine	I	53	126.9	Thulium	Tm	69	168.9
Iridium	Ir	77	192.2	Tin	Sn	50	118.7
Iron	Fe	26	55.8	Titanium	Ti	22	47.9
Krypton	Kr	36	83.8	Tungsten	W	74	183.8
Lanthanum	La	57	138.9	Uranium	U	92	238.0
Lawrencium	Lr	103	(262)	Vanadium	V	23	50.9
Lead	Pb	82	207.2	Xenon	Xe	54	131.3
Lithium	Li	3	6.9	Ytterbium	Yb	70	173.0
Lutetium	Lu	71	175.0	Yttrium	Y	39	88.9
Magnesium	Mg	12	24.3	Zinc	Zn	30	65.4
Manganese	Mn	25	54.9	Zirconium	Zr	40	91.2
Mendelevium	Md	101	(258)				

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

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

* Aqueous solutions are readily oxidized by air.

** Not stable in aqueous solutions.

Negative ions (anions)	
Bromide	Br^{-}
Carbonate	CO_3^{2-}
Chlorate	ClO_3^{-}
Chloride	Cl^{-}
Chlorite	ClO_2^{-}
Chromate	CrO_4^{2-}
Cyanide	CN^{-}
Dichromate	$Cr_2O_7^{2-}$
Dihydrogen phosphate	$H_2PO_4^{-}$
Ethanoate, Acetate	CH_3COO^{-}
Fluoride	F^{-}
Hydrogen carbonate, bicarbonate	HCO_3^{-}
Hydrogen oxalate, binoxalate	$HC_2O_4^{-}$
Hydrogen sulphate, bisulphate	HSO_4^{-}
Hydrogen sulphide, bisulphide	HS^{-}
Hydrogen sulphite, bisulphite	HSO_3^{-}
Hydroxide	OH^{-}
Hypochlorite	ClO^{-}
Iodide	I^{-}
Monohydrogen phosphate	HPO_4^{2-}
Nitrate	NO_3^{-}
Nitrite	NO_2^{-}
Oxalate	$C_2O_4^{2-}$
Oxide**	O^{2-}
Perchlorate	ClO_4^{-}
Permanganate	MnO_4^{-}
Phosphate	PO_4^{3-}
Sulphate	SO_4^{2-}
Sulphide	S^{2-}
Sulphite	SO_3^{2-}
Thiocyanate	SCN^{-}

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > $0.1\ \text{mol/L}$ at 25^{o}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 BRÖNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature

Strength of Acid	Name of Acid	Acid		Base	K_a	Strength of Base
Strong ↑	Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large	Weak ↓
	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^+	$\rightleftharpoons$	$H^+ + H_2O$	1.0	
	Iodic	HIO_3	$\rightleftharpoons$	$H^+ + IO_3^-$	1.7×10^{-1}	
	Oxalic	$H_2C_2O_4$	$\rightleftharpoons$	$H^+ + HC_2O_4^-$	5.9×10^{-2}	
	Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftharpoons$	$H^+ + HSO_3^-$	1.5×10^{-2}	
	Hydrogen sulphate ion	HSO_4^-	$\rightleftharpoons$	$H^+ + SO_4^{2-}$	1.2×10^{-2}	
	Phosphoric	H_3PO_4	$\rightleftharpoons$	$H^+ + H_2PO_4^-$	7.5×10^{-3}	
	Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftharpoons$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}	
	Citric	$H_3C_6H_5O_7$	$\rightleftharpoons$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}	
	Nitrous	HNO_2	$\rightleftharpoons$	$H^+ + NO_2^-$	4.6×10^{-4}	
	Hydrofluoric	HF	$\rightleftharpoons$	$H^+ + F^-$	3.5×10^{-4}	
	Methanoic, formic	$HCOOH$	$\rightleftharpoons$	$H^+ + HCOO^-$	1.8×10^{-4}	
	Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftharpoons$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}	
	Benzoic	C_6H_5COOH	$\rightleftharpoons$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}	
	Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftharpoons$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}	
	Ethanoic, acetic	CH_3COOH	$\rightleftharpoons$	$H^+ + CH_3COO^-$	1.8×10^{-5}	
	Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftharpoons$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}	
	Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftharpoons$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}	
	Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftharpoons$	$H^+ + HCO_3^-$	4.3×10^{-7}	
	Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftharpoons$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}	
	Hydrogen sulphite ion	HSO_3^-	$\rightleftharpoons$	$H^+ + SO_3^{2-}$	1.0×10^{-7}	
	Hydrogen sulphide	H_2S	$\rightleftharpoons$	$H^+ + HS^-$	9.1×10^{-8}	
	Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftharpoons$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}	
	Boric	H_3BO_3	$\rightleftharpoons$	$H^+ + H_2BO_3^-$	7.3×10^{-10}	
	Ammonium ion	NH_4^+	$\rightleftharpoons$	$H^+ + NH_3$	5.6×10^{-10}	
	Hydrocyanic	HCN	$\rightleftharpoons$	$H^+ + CN^-$	4.9×10^{-10}	
	Phenol	C_6H_5OH	$\rightleftharpoons$	$H^+ + C_6H_5O^-$	1.3×10^{-10}	
	Hydrogen carbonate ion	HCO_3^-	$\rightleftharpoons$	$H^+ + CO_3^{2-}$	5.6×10^{-11}	
	Hydrogen peroxide	H_2O_2	$\rightleftharpoons$	$H^+ + HO_2^-$	2.4×10^{-12}	
	Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftharpoons$	$H^+ + PO_4^{3-}$	2.2×10^{-13}	
	Water	H_2O	$\rightleftharpoons$	$H^+ + OH^-$	1.0×10^{-14}	
	Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small	
Weak	Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small	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 1*M* in Water at 25° C

STRENGTH OF OXIDIZING AGENT	OXIDIZING AGENTS		REDUCING AGENTS	E°(VOLTS)	STRENGTH OF REDUCING AGENT
strong	$F_{2(g)} + 2e^-$	⇄	$2F^-$	+2.87	weak
	$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+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	
	$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_{2(l)} + 3H_2O$	+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	Overpotential Effect
	$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+1.20	
	$Br_{2(l)} + 2e^-$	⇄	$2Br^-$	+1.09	
	$AuCl_4^- + 3e^-$	⇄	$Au_{(s)} + 4Cl^-$	+1.00	
	$NO_3^- + 4H^+ + 3e^-$	⇄	$NO_{(g)} + 2H_2O$	+0.96	
	$Hg^{2+} + 2e^-$	⇄	$Hg_{(l)}$	+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	
	$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg_{(l)}$	+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	
Overpotential Effect	$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−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	
weak	$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04	strong