INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

AUGUST 1998

PROVINCIAL EXAMINATION

MINISTRY OF EDUCATION

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

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

		Value	Suggested Time
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. Consider the following reaction:

$$HgO_{(s)} \rightarrow Hg_{(\ell)} + \frac{1}{2}O_{2(g)}$$

The rate of this reaction can be expressed as

A. rate $= [O_2]^{\frac{1}{2}}$

B. rate $= \frac{\Delta[O_2]}{\Delta t}$

C. rate $= \frac{\Delta[Hg]}{\Delta t}$

D. rate $= \frac{\Delta[HgO]}{\Delta t}$

2. Which of the following would react most rapidly?

A. Powdered Zn in 1.0 M HCl at $25°$ C
B. Powdered Zn in 2.0 M HCl at $40°$ C
C. A lump of Zn in 2.0 M HCl at $25°$ C
D. A lump of Zn in 1.0 M HCl at $40°$ C

3. When a collision occurs between two reactant species which possess between them the minimum kinetic energy, called activation energy, a product does not always form. This may be a result of

A. low temperature.
B. small surface area.
C. low concentrations.
D. unfavourable geometry.

OVER

4. Addition of a catalyst to a reaction increases the rate because it

A. increases the value of ΔH.
B. decreases the value of ΔH.
C. provides an alternate reaction mechanism with a lower activation energy.
D. provides an alternate reaction mechanism with a higher activation energy.

5. Consider the following equilibrium reaction:

$$PCl_{5(g)} + \text{energy} \rightleftarrows PCl_{3(g)} + Cl_{2(g)}$$

The temperature of this system is decreased. What is the immediate effect on the reaction rates?

A. Both forward and reverse rates increase.
B. Both forward and reverse rates decrease.
C. Forward rate decreases while reverse rate increases.
D. Forward rate increases while reverse rate decreases.

6. Which of the following describes all chemical equilibrium systems?

A. The mass of the reactants equals the mass of the products.
B. The species are present in the same ratio as in the balanced equation.
C. The rate of the forward reaction equals the rate of the reverse reaction.
D. The concentration of the reactants equals the concentration of the products.

7. In which reaction is entropy decreasing?

A. $H_2O_{(\ell)} \rightarrow H_2O_{(g)}$
B. $N_2O_{4(g)} \rightarrow 2\,NO_{2(g)}$
C. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
D. $Fe^{3+}{}_{(aq)} + SCN^{-}{}_{(aq)} \rightarrow FeSCN^{2+}{}_{(aq)}$

8. Consider the following equilibrium:

$$C_{(s)} + 2H_{2(g)} \rightleftarrows CH_{4(g)}$$

The addition of H_2 will cause the equilibrium to shift to the

A. left and $[CH_4]$ will increase.
B. left and $[CH_4]$ will decrease.
C. right and $[CH_4]$ will increase.
D. right and $[CH_4]$ will decrease.

9. Consider the following equilibrium:

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

Initially, 0.100 mol HBr is placed into a 2.0 L container. At equilibrium, there are 0.040 mol HBr present. The equilibrium concentration of H_2 is

A. 0.0050 mol/L
B. 0.010 mol/L
C. 0.015 mol/L
D. 0.030 mol/L

10. Consider the following equilibrium:

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

The equilibrium expression is

A. $K_{eq} = \dfrac{[SO_3]}{[SO_2][O_2]}$

B. $K_{eq} = \dfrac{[SO_3]^2}{[SO_2]^2[O_2]}$

C. $K_{eq} = \dfrac{[SO_2][O_2]}{[SO_3]}$

D. $K_{eq} = \dfrac{[SO_2]^2[O_2]}{[SO_3]^2}$

OVER

11. Consider the following equilibrium:

$$\text{energy} + SbCl_{5(g)} \rightleftarrows SbCl_{3(g)} + Cl_{2(g)}$$

The K_{eq} decreases when

A. $SbCl_5$ is added.
B. $SbCl_5$ is removed.
C. the temperature is increased.
D. the temperature is decreased.

12. Consider the following equilibrium:

$$2NO_{(g)} + 2H_{2(g)} \rightleftarrows N_{2(g)} + 2H_2O_{(g)} \qquad K_{eq} = 1.3 \times 10^2$$

A 1.0 L container is initially filled with 1.0 mol of each of the species in the reaction. The equilibrium shifts to the

A. left because Trial $K_{eq} > K_{eq}$
B. left because Trial $K_{eq} < K_{eq}$
C. right because Trial $K_{eq} > K_{eq}$
D. right because Trial $K_{eq} < K_{eq}$

13. In 0.20 M Na_2CrO_4, the ion concentrations are

	$[Na^+]$	$[CrO_4^{2-}]$
A.	0.40 M	0.20 M
B.	0.20 M	0.20 M
C.	0.20 M	0.40 M
D.	0.40 M	0.80 M

14. Which of the following compounds is the least soluble in water?

A. H_2S
B. KNO_3
C. $ZnSO_4$
D. $Ca(OH)_2$

15. Which of the following 0.20 M solutions will **not** form a precipitate when mixed with an equal volume of 0.20 M $Sr(OH)_2$?

A. CaS

B. NH_4Cl

C. Na_2SO_4

D. $Ba(NO_3)_2$

16. Consider the following equilibrium:

$$SrF_{2(s)} \rightleftarrows Sr^{2+}{}_{(aq)} + 2F^{-}{}_{(aq)}$$

The equilibrium will shift left upon the addition of

A. $H_2O_{(\ell)}$

B. $SrF_{2(s)}$

C. $SrCl_{2(s)}$

D. $NaNO_{3(s)}$

17. Two ions found in hard water are Ca^{2+} and Mg^{2+}. Which of the following will precipitate only one of these ions?

A. I^{-}

B. S^{2-}

C. $SO_4{}^{2-}$

D. $CO_3{}^{2-}$

18. At $25°C$, the solubility of AgBr is

A. 2.9×10^{-25} M

B. 5.4×10^{-13} M

C. 2.7×10^{-13} M

D. 7.3×10^{-7} M

OVER

19. Which of the following saturated solutions has the greatest $\left[CO_3^{2-}\right]$?

A. $SrCO_3$
B. $CaCO_3$
C. $BaCO_3$
D. $MgCO_3$

20. Which of the following will neutralize H_2SO_4 and form a precipitate at the same time?

A. NH_3
B. KOH
C. $CaCl_2$
D. $Sr(OH)_2$

21. Both acidic and basic solutions

A. taste sour.
B. feel slippery.
C. conduct electricity.
D. turn blue litmus red.

22. The conjugate acid of the monohydrogen phosphate ion, $HPO_4^{\ 2-}$, is

A. $PO_4^{\ 3-}$
B. $H_2PO_4^{\ -}$
C. $H_2PO_4^{2-}$
D. $H_2PO_4^{3-}$

23. Which of the following is the strongest base?

A. HSO_4^-
B. HSO_3^-
C. HCO_3^-
D. $HC_2O_4^-$

24. Which of the following are amphiprotic in aqueous solution?

I	HBr
II	H_2O
III	HCO_3^-
IV	$H_2C_6H_5O_7^-$

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

25. What is the value of K_w at $25°C$?

A. 1.0×10^{-14}
B. 1.0×10^{-7}
C. 7
D. 14

26. Consider the following equilibrium:

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

A small amount of $Fe(H_2O)_6^{3+}$ is added to water and equilibrium is re-established. Which of the following represent the changes in the ion concentrations?

	$[H_3O^+]$	$[OH^-]$
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

OVER

27. Consider the following equilibrium:

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

When the temperature of water is changed, the pH decreases. Which of the following explains this pH change?

A. Temperature and K_w both increase.
B. Temperature and K_w both decrease.
C. Temperature increases and K_w decreases.
D. Temperature decreases and K_w increases.

28. The pOH of a 0.015 M HCl solution is

A. 0.97
B. 1.82
C. 12.18
D. 13.03

29. What is the value of K_b for $HC_6H_5O_7^{2-}$?

A. 5.9×10^{-10}
B. 2.4×10^{-8}
C. 4.1×10^{-7}
D. 1.7×10^{-5}

30. Which of the following will produce an acidic solution?

A. KNO_3
B. NH_4NO_3
C. $Ca(NO_3)_2$
D. $Ba(NO_3)_2$

31. Consider the following equilibrium for an indicator:

$$HInd + H_2O \rightleftarrows H_3O^+ + Ind^-$$

In a solution with a pH of 6.8, the colour of bromthymol blue is

A. blue because $[HInd] = [Ind^-]$

B. green because $[HInd] = [Ind^-]$

C. green because $[HInd] < [Ind^-]$

D. yellow because $[HInd] > [Ind^-]$

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

A. neutral red.
B. methyl orange.
C. indigo carmine.
D. phenolphthalein.

33. A 25.00 mL sample of $Sr(OH)_2$ is completely neutralized by 28.60 mL of 0.100 M HCl. The concentration of the $Sr(OH)_2$ is

A. 1.43×10^{-3} M

B. 2.86×10^{-3} M

C. 5.72×10^{-2} M

D. 1.14×10^{-1} M

34. A student mixes 15.0 mL of 0.100 M NaOH with 10.0 mL of 0.200 M HCl. The resulting solution is

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

OVER

35. A buffer solution can be prepared by combining equal moles of a

A. strong acid and a strong base.
B. weak acid and its conjugate base.
C. strong base and its conjugate acid.
D. strong acid and its conjugate base.

36. Which of the following could be the pH of a sample of acid rain?

A. 0
B. 4
C. 7
D. 10

37. A product of the oxidation of MnO_2 is

A. Mn
B. Mn^{2+}
C. MnO_4^{-}
D. Mn_2O_3

38. Consider the following:

$$3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$$

In the redox reaction above,

A. hydrogen is both reduced and oxidized.
B. manganese is both reduced and oxidized.
C. manganese is reduced and hydrogen is oxidized.
D. manganese is oxidized and hydrogen is reduced.

39. The oxidation number of phosphorus in $Na_4P_2O_7$ is

A. −10
B. −5
C. +5
D. +10

40. Consider the following:

$$Br_2 + SO_2 + 2H_2O \rightarrow 2Br^- + SO_4^{2-} + 4H^+$$

In this redox reaction, the chemical species SO_2 is

A. reduced and the oxidation number of oxygen increases.
B. reduced and the oxidation number of oxygen decreases.
C. oxidized and the oxidation number of sulphur increases.
D. oxidized and the oxidation number of sulphur decreases.

41. In an experiment to determine the relative strength of oxidizing agents, three metals, Ag, Ru and Pd were placed into solutions containing a cation of the other two metals. The results were recorded in the following data table:

METAL \ SOLUTION	Pd^{2+}	Ru^{2+}	Ag^+
Ag	reaction	no reaction	
Ru	reaction		reaction
Pd		no reaction	no reaction

The relative strength of oxidizing agents is

A. Ru > Ag > Pd
B. Pd > Ag > Ru
C. $Ru^{2+} > Ag^+ > Pd^{2+}$
D. $Pd^{2+} > Ag^+ > Ru^{2+}$

42. Consider the following:

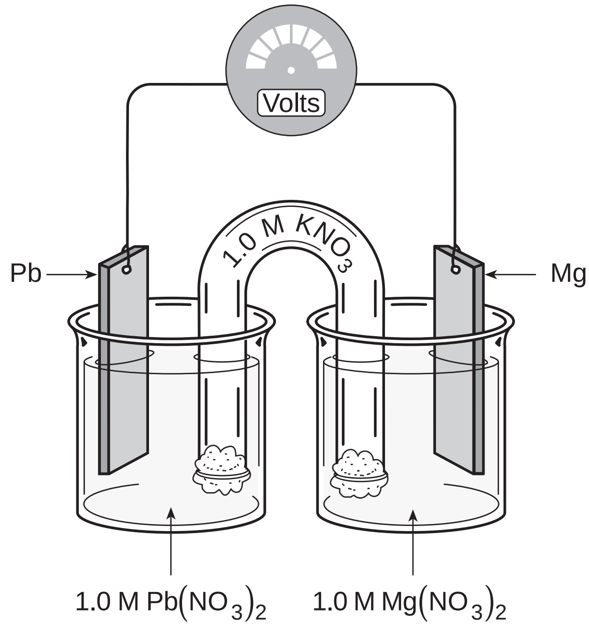
$$4ReO_3 + OsO_4 + 2H_2O \rightarrow 4ReO_4^- + OsO_2 + 4H^+$$

The equation for the oxidation half-reaction is

A. $ReO_3 + H_2O \rightarrow ReO_4^- + 2H^+ + e^-$
B. $ReO_3 + H_2O + e^- \rightarrow ReO_4^- + 2H^+$
C. $OsO_4 + 4H^+ \rightarrow OsO_2 + 2H_2O + 4e^-$
D. $OsO_4 + 4H^+ + 4e^- \rightarrow OsO_2 + 2H_2O$

OVER

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



43. In the electrochemical cell above, the reaction at the anode is

A. $Pb \rightarrow Pb^{2+} + 2e^-$
B $Pb^{2+} + 2e^- \rightarrow Pb$
C. $Mg \rightarrow Mg^{2+} + 2e^-$
D. $Mg^{2+} + 2e^- \rightarrow Mg$

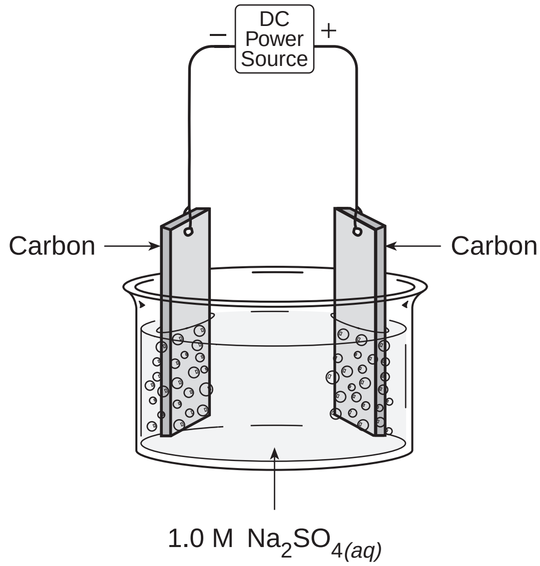
44. The $E°$ of the cell above is

A. -2.50 V
B. -2.24 V
C. $+2.24$ V
D. $+2.50$ V

45. As the cell operates, the mass of

A. both the lead and magnesium electrodes increase.
B. both the lead and magnesium electrodes decrease.
C. the lead electrode decreases and the magnesium electrode increases.
D. the lead electrode increases and the magnesium electrode decreases.

Use the following diagram to answer question 46.



46. The gas produced at the anode is

   A. oxygen.
   B. hydrogen.
   C. water vapour.
   D. sulphur dioxide.

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47. The cathodic protection of iron may be accomplished by using

   A. Zn
   B. Sn
   C. Cu
   D. Ni

48. To determine $\left[Sn^{2+}\right]$ by redox titration, a suitable reagent that may be used is an acidified solution of

   A. I^-
   B. Co^{2+}
   C. Cr^{3+}
   D. $Cr_2O_7^{2-}$

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

OVER

PART B: WRITTEN RESPONSE

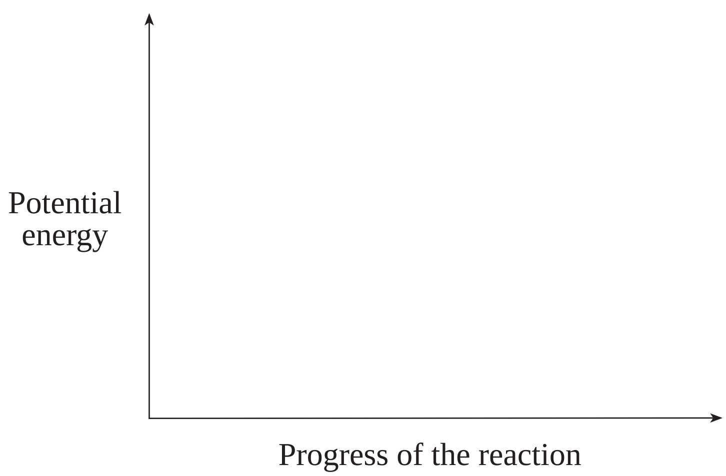
Value: 32 marks **Suggested Time: 50 minutes**

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. Sketch a potential energy diagram for an endothermic reaction in the space below.

   On your diagram, label:

   i) the energy of the activated complex
   ii) the activation energy
   iii) ΔH **(3 marks)**



2. Consider the following equilibrium:

$$H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)} \qquad K_{eq} = 49$$

A 1.00 L container is initially filled with 0.180 mol HI.
Calculate the concentration of HI at equilibrium. **(4 marks)**

OVER

3. What is the maximum $\left[Mg^{2+}\right]$ that can exist in a solution with a pOH of 2.00? **(3 marks)**

4. When 1.00 L of a saturated solution of CaF_2 was evaporated to dryness, 2.66×10^{-2} g of residue was formed. Calculate the value of K_{sp}. **(3 marks)**

5. Consider the reaction between HCO_3^- and $HC_2O_4^-$.

a) Write the equation for the predominant reaction. **(1 mark)**

b) Identify the Brönsted-Lowry acids in the reaction above. **(1 mark)**

c) Explain why products are favoured in the reaction above. **(1 mark)**

____

____

OVER

6. A 3.50×10^{-3} M sample of the unknown acid, HA, has a pH of 2.90.
Calculate the value of K_a and identify this acid. **(4 marks)**

7. a) Write two equations representing the acidic and basic hydrolysis of $NaHSO_{3(s)}$. **(2 marks)**

b) Use calculations to determine if the solution is acidic or basic. **(2 marks)**

OVER

8. Define the term *oxidation-reduction reaction*. **(2 marks)**

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9. Balance the following half-reaction: **(3 marks)**

$$In_2O_3 \rightarrow In \quad \text{(basic)}$$

10. Consider the following:

$$MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

A 20.00 mL sample of a solution containing $\left[Fe^{2+}\right]$ was titrated using 0.0184 M $KMnO_4$ and the following data were collected.

	TRIAL 1	TRIAL 2	TRIAL 3
Volume of $KMnO_{4(aq)}$ used	29.07 mL	26.55 mL	26.45 mL

Calculate the concentration of Fe^{2+} in the solution. **(3 marks)**

END OF EXAMINATION

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CHEMISTRY 12

August 1998

Course Code = CH

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CHEMISTRY 12

August 1998

Course Code = CH

Score for Question 1:	Score for Question 8:
1. ______ (3)	8. ______ (2)

Score for Question 2:	Score for Question 9:
2. ______ (4)	9. ______ (3)

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

Score for Question 4:

4. ______ (3)

Score for Question 5:

5. ______ (3)

Score for Question 6:

6. ______ (4)

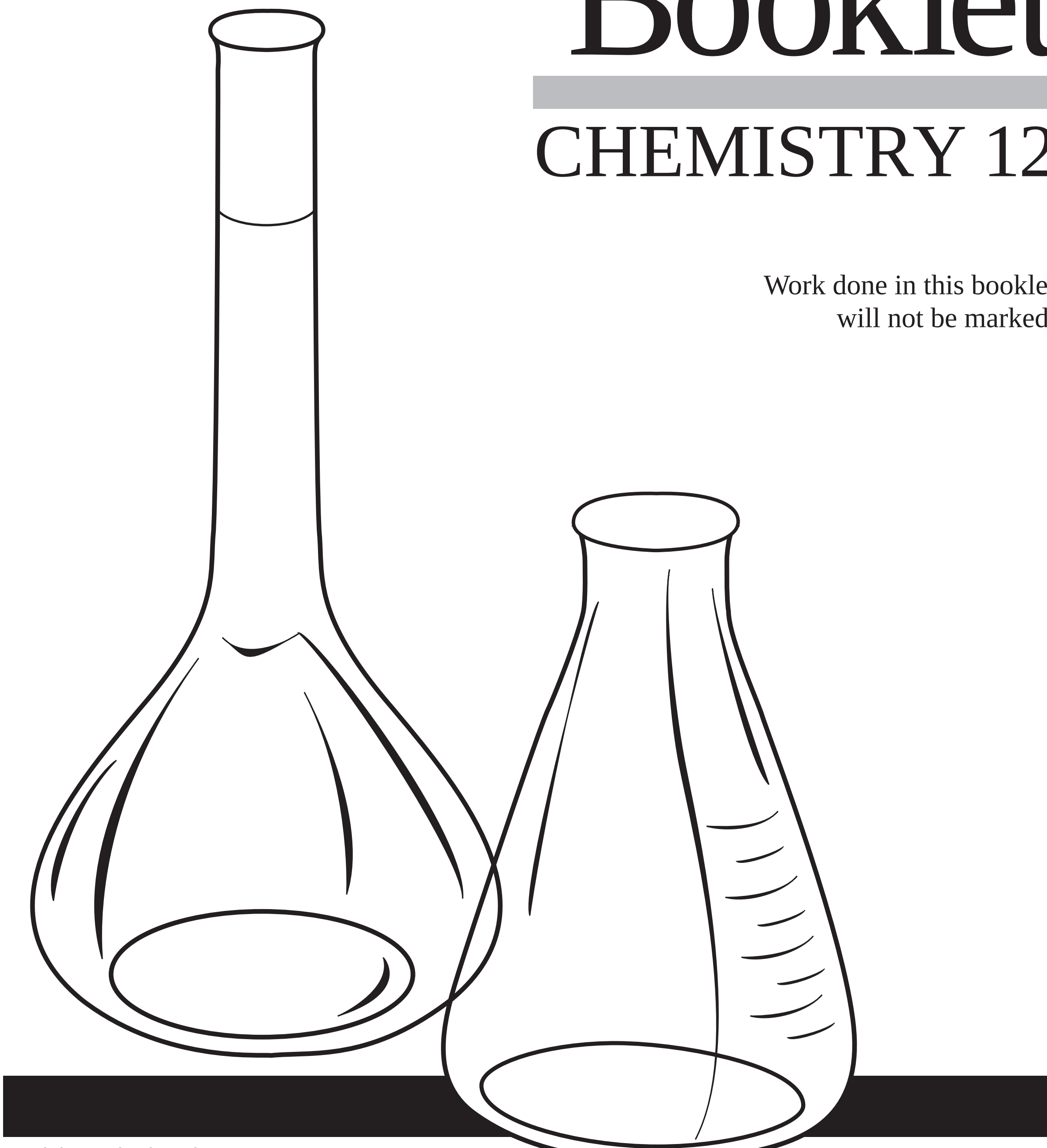
Score for Question 7:

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

14 — Atomic number
Si — Symbol
Silicon — Name
28.1 — Atomic mass

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)									

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.

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)

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)		Negative ions (anions)	
Aluminum	Al^{3+}	Bromide	Br^{-}
Ammonium	NH_4^{+}	Carbonate	CO_3^{2-}
Barium	Ba^{2+}	Chlorate	ClO_3^{-}
Calcium	Ca^{2+}	Chloride	Cl^{-}
Chromium(II), chromous	Cr^{2+}	Chlorite	ClO_2^{-}
Chromium(III), chromic	Cr^{3+}	Chromate	CrO_4^{2-}
Copper(I)*, cuprous	Cu^{+}	Cyanide	CN^{-}
Copper(II), cupric	Cu^{2+}	Dichromate	$Cr_2O_7^{2-}$
Hydrogen	H^{+}	Dihydrogen phosphate	$H_2PO_4^{-}$
Hydronium	H_3O^{+}	Ethanoate, Acetate	CH_3COO^{-}
Iron(II)*, ferrous	Fe^{2+}	Fluoride	F^{-}
Iron(III), ferric	Fe^{3+}	Hydrogen carbonate, bicarbonate	HCO_3^{-}
Lead(II), plumbous	Pb^{2+}	Hydrogen oxalate, binoxalate	$HC_2O_4^{-}$
Lead(IV), plumbic	Pb^{4+}	Hydrogen sulphate, bisulphate	HSO_4^{-}
Lithium	Li^{+}	Hydrogen sulphide, bisulphide	HS^{-}
Magnesium	Mg^{2+}	Hydrogen sulphite, bisulphite	HSO_3^{-}
Manganese(II), manganous	Mn^{2+}	Hydroxide	OH^{-}
Manganese(IV)	Mn^{4+}	Hypochlorite	ClO^{-}
Mercury(I)*, mercurous	Hg_2^{2+}	Iodide	I^{-}
Mercury(II), mercuric	Hg^{2+}	Monohydrogen phosphate	HPO_4^{2-}
Potassium	K^{+}	Nitrate	NO_3^{-}
Silver	Ag^{+}	Nitrite	NO_2^{-}
Sodium	Na^{+}	Oxalate	$C_2O_4^{2-}$
Tin(II)*, stannous	Sn^{2+}	Oxide**	O^{2-}
Tin(IV), stannic	Sn^{4+}	Perchlorate	ClO_4^{-}
Zinc	Zn^{2+}	Permanganate	MnO_4^{-}
		Phosphate	PO_4^{3-}
		Sulphate	SO_4^{2-}
		Sulphide	S^{2-}
		Sulphite	SO_3^{2-}
		Thiocyanate	SCN^{-}

* Aqueous solutions are readily oxidized by air.

** Not stable in aqueous solutions.

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at $25^{\circ}C$.

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	
	$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+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	Overpotential Effect
	$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+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	
Overpotential Effect	$2H_2O + 2e^-$	⇄	$H_2 + 2OH^-(10^{-7}M)$	−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	
weak	$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04	strong