INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

JANUARY 1997

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. **Under no circumstance is your name or identification, other than your Student I.D. Number, to appear on this paper.**
2. Take the separate Answer Sheet and follow the directions on its front page.
3. Be sure you have an **HB pencil** and an eraser for completing your Answer Sheet. Follow the directions on the Answer Sheet when answering multiple-choice questions.
4. For each of the written-response questions, write your answer in the space provided.
5. 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**.
6. At the end of the examination, place your Answer Sheet inside the front cover of this booklet and return the booklet and your Answer Sheet to the supervisor.

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FOR OFFICE USE ONLY

INSERT STUDENT I.D. NUMBER (PEN)

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________ – ________

CHEMISTRY 12 JANUARY 1997 PROVINCIAL

Course Code = CH   Examination Type = P

1. ______ (2)

2. ______ (2)

3. ______ (2)

4. ______ (3)

5. ______ (2)

6. ______ (3)

7. ______ (3)

8. ______ (3)

9. ______ (4)

10. ______ (3)

11. ______ (5)

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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:	11 written-response questions	32	50
	Total:	**80 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 Brönsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

3. An approved scientific calculator is essential for the examination. The calculator must be a hand-held device designed **only** for mathematical computations such as logarithmic and trigonometric functions. It **can be** programmable, but **must not** contain any graphing capabilities. You **must not** bring into the examination room any devices to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, or keyboards.

4. You have **two hours** to complete this examination.

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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 Answer Sheet provided. Using an HB pencil, completely fill in the circle that has the letter corresponding to your answer.

1. Which of the following factors affects the rate of heterogeneous reactions only?

A. nature of reactants
B. temperature of system
C. surface area of reactants
D. concentration of reactants

2. A 25.0 mL sample of hydrogen peroxide decomposes producing 50.0 mL of oxygen gas in 137 s. The rate of formation of O_2 in mL/min is

A. 0.182 mL/min
B. 0.365 mL/min
C. 10.9 mL/min
D. 21.9 mL/min

3. For collisions to be successful, reactants must have

A. favourable geometry only.
B. sufficient heat of reaction only.
C. sufficient potential energy only.
D. sufficient kinetic energy and favourable geometry.

4. Consider the following reaction:

$$\tfrac{1}{2}H_{2(g)} + \tfrac{1}{2}I_{2(g)} \rightarrow HI_{(g)} \qquad \Delta H = +28\text{ kJ}$$

The activation energy for the formation of HI is 167 kJ. The activation energy for the decomposition of HI is

A. 28 kJ
B. 139 kJ
C. 167 kJ
D. 195 kJ

OVER

5. Consider the following reaction mechanism:

$$\text{Step 1:}\quad NO_{(g)} + O_{3(g)} \rightarrow NO_{2(g)} + O_{2(g)}$$

$$\text{Step 2:}\quad O_{(g)} + NO_{2(g)} \rightarrow NO_{(g)} + O_{2(g)}$$

The catalyst is

A. O_2
B. O_3
C. NO
D. NO_2

6. Consider the following:

$$2NH_{3(g)} \rightleftarrows N_{2(g)} + 3H_{2(g)}$$

A flask is initially filled with NH_3. As the system approaches equilibrium, the rate of the forward reaction

A. increases as the rate of the reverse reaction decreases.
B. decreases as the rate of the reverse reaction increases.
C. increases as the rate of the reverse reaction increases.
D. decreases as the rate of the reverse reaction decreases.

7. Consider the following reaction:

$$Na_2CO_{3(s)} + 2HCl_{(aq)} \rightarrow 2NaCl_{(aq)} + CO_{2(g)} + H_2O_{(\ell)} \qquad \Delta H = -27.7 \text{ kJ}$$

In this reaction,

A. minimum enthalpy and maximum entropy both favour products.
B. minimum enthalpy and maximum entropy both favour reactants.
C. minimum enthalpy favours products and maximum entropy favours reactants.
D. minimum enthalpy favours reactants and maximum entropy favours products.

8. Consider the following equilibrium:

$$CH_{4(g)} + H_2O_{(g)} + \text{heat} \rightleftarrows CO_{(g)} + 3H_{2(g)}$$

In which of the following will both stresses shift the equilibrium right?

A. a decrease in temperature and a decrease in volume
B. an increase in temperature and a decrease in volume
C. a decrease in temperature and an increase in volume
D. an increase in temperature and an increase in volume

9. Consider the following equilibrium:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad \Delta H = -198 \text{ kJ}$$

There will be no shift in this equilibrium when

A. more O_2 is added.
B. a catalyst is added.
C. the volume is increased.
D. the temperature is increased.

10. Consider the following equilibrium:

$$2Fe_{(s)} + 3H_2O_{(g)} \rightleftarrows Fe_2O_{3(s)} + 3H_{2(g)}$$

The equilibrium constant expression is

A. $K_{eq} = \dfrac{[Fe_2O_3][H_2]^3}{[Fe]^2[H_2O]^3}$

B. $K_{eq} = \dfrac{[Fe_2O_3][3H_2]}{[2Fe][3H_2O]}$

C. $K_{eq} = \dfrac{[H_2]^3}{[H_2O]^3}$

D. $K_{eq} = [H_2]^3$

OVER

11. Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 0.133$$

At equilibrium, the $[N_2O_4]$ is equal to

A. $\frac{0.133}{[NO_2]}$

B. $\frac{[NO_2]}{0.133}$

C. $\frac{0.133}{[NO_2]^2}$

D. $\frac{[NO_2]^2}{0.133}$

12. Consider the following equilibrium:

$$CaCO_{3(s)} + 556\text{ kJ} \rightleftarrows CaO_{(s)} + CO_{2(g)}$$

The value of the equilibrium constant will increase when

A. CO_2 is added.
B. CO_2 is removed.
C. the temperature is increased.
D. the temperature is decreased.

13. Consider the following equilibrium:

$$C_{(s)} + H_2O_{(g)} \rightleftarrows CO_{(g)} + H_{2(g)}$$

The contents of a 1.00 L container at equilibrium were analyzed and found to contain 0.20 mol C, 0.20 mol H_2O, 0.60 mol CO and 0.60 mol H_2. The equilibrium constant is

A. 0.11
B. 0.56
C. 1.8
D. 9.0

14. When a student mixes equal volumes of 0.20 M Na_2S and 0.20 M $Sr(OH)_2$,

A. no precipitate forms.
B. a precipitate of only SrS forms.
C. a precipitate of only NaOH forms.
D. precipitates of both NaOH and SrS form.

15. A student wishes to identify an unknown cation in a solution. A precipitate does not form with the addition of SO_4^{2-}, but does form with the addition of S^{2-}. Which of the following is the unknown cation?

A. Ag^+
B. Mg^{2+}
C. Ca^{2+}
D. Cu^{2+}

16. When dissolved in water, which of the following produces an ionic solution?

A. O_2
B. CH_4
C. $CaCl_2$
D. $C_{12}H_{22}O_{11}$

17. The solubility of MnS is $4.8\times10^{-7}\,M$, at $25°C$. The K_{sp} value is

A. 2.3×10^{-13}
B. 4.8×10^{-7}
C. 9.6×10^{-7}
D. 6.9×10^{-4}

18. Which of the following units is commonly used to describe solubility?

A. mL/s
B. g/°C
C. mol/L
D. °C/mol

OVER

19. A 200.0 mL solution contains 0.050 mol of $\mathrm{Ba(NO_3)_2}$. The $\left[\mathrm{NO_3}^-\right]$ is

A. 0.050 M
B. 0.10 M
C. 0.25 M
D. 0.50 M

20. Consider the following solubility equilibrium:

$$\mathrm{MgCO_{3(s)}} \rightleftarrows \mathrm{Mg^{2+}}_{(aq)} + \mathrm{CO_3}^{2-}{}_{(aq)}$$

The addition of which of the following substances would decrease the solubility of $\mathrm{MgCO_3}$?

A. $\mathrm{H_2O}$
B. NaCl
C. NaOH
D. $\mathrm{Na_2CO_3}$

21. A basic solution

A. tastes sour.
B. feels slippery.
C. does not conduct electricity.
D. reacts with metals to release oxygen gas.

22. The balanced formula equation for the neutralization of $\mathrm{H_2SO_4}$ by KOH is

A. $\mathrm{H_2SO_4 + KOH \rightarrow KSO_4 + H_2O}$
B. $\mathrm{H_2SO_4 + KOH \rightarrow K_2SO_4 + H_2O}$
C. $\mathrm{H_2SO_4 + 2KOH \rightarrow K_2SO_4 + H_2O}$
D. $\mathrm{H_2SO_4 + 2KOH \rightarrow K_2SO_4 + 2H_2O}$

23. An Arrhenius base is defined as a substance which

A. donates protons.
B. donates electrons.
C. produces H^+ in solution.
D. produces OH^- in solution.

24. Consider the following equilibrium:

$$HS^- + H_3PO_4 \rightleftarrows H_2S + H_2PO_4{}^-$$

The order of Brönsted-Lowry acids and bases is

A. acid, base, acid, base.
B. acid, base, base, acid.
C. base, acid, acid, base.
D. base, acid, base, acid.

25. The equation representing the reaction of ethanoic acid with water is

A. $CH_3COO^- + H_2O \rightleftarrows CH_3COOH + OH^-$
B. $CH_3COO^- + H_2O \rightleftarrows CH_2COO^{2-} + H_3O^+$
C. $CH_3COOH + H_2O \rightleftarrows CH_3COO^- + H_3O^+$
D. $CH_3COOH + H_2O \rightleftarrows CH_3COOH_2{}^+ + OH^-$

26. Consider the following equilibrium:

$$2H_2O_{(\ell)} + 57\text{ kJ} \rightleftarrows H_3O^+{}_{(aq)} + OH^-{}_{(aq)}$$

When the temperature is decreased, the water

A. stays neutral and $\left[H_3O^+\right]$ increases.
B. stays neutral and $\left[H_3O^+\right]$ decreases.
C. becomes basic and $\left[H_3O^+\right]$ decreases.
D. becomes acidic and $\left[H_3O^+\right]$ increases.

OVER

27. In a solution at $25°C$, the $\left[H_3O^+\right]$ is 3.5×10^{-6} M. The $\left[OH^-\right]$ is

A. 3.5×10^{-20} M
B. 2.9×10^{-9} M
C. 1.0×10^{-7} M
D. 3.5×10^{-6} M

28. In a solution with a pOH of 4.22, the $\left[OH^-\right]$ is

A. 1.7×10^{-10} M
B. 6.0×10^{-5} M
C. 6.3×10^{-1} M
D. 1.7×10^{4} M

29. An aqueous solution of NH_4CN is

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

30. The net ionic equation for the predominant hydrolysis reaction of $KHSO_4$ is

A. $HSO_4^- + H_2O \rightleftarrows SO_4^{2-} + H_3O^+$
B. $HSO_4^- + H_2O \rightleftarrows H_2SO_4 + OH^-$
C. $KHSO_4 + H_2O \rightleftarrows K^+ + SO_4^{2-} + H_3O^+$
D. $KHSO_4 + H_2O \rightleftarrows K^+ + H_2SO_4 + OH^-$

31. Consider the following equilibrium for an indicator:

$$\mathrm{HInd} + \mathrm{H_2O} \rightleftarrows \mathrm{Ind^-} + \mathrm{H_3O^+}$$

At the transition point,

A. $[\mathrm{HInd}] > [\mathrm{Ind^-}]$
B. $[\mathrm{HInd}] = [\mathrm{Ind^-}]$
C. $[\mathrm{HInd}] < [\mathrm{Ind^-}]$
D. $[\mathrm{HInd}] = [\mathrm{H_3O^+}]$

32. The equivalence point in a titration is reached when 20.0 mL of H_2SO_4 is added to 20.0 mL of 0.420 M KOH. The $[H_2SO_4]$ in the original solution is

A. 0.00840 M
B. 0.210 M
C. 0.420 M
D. 0.840 M

33. In a titration between a weak acid and a strong base, the pH at the equivalence point is

A. 3
B. 5
C. 7
D. 9

34. The pH of 100.0 mL of 0.0050 M NaOH solution is

A. 2.30
B. 3.30
C. 10.70
D. 11.70

35. A buffer solution is prepared by adding 1.0 mol of $NaCH_3COO$ to 1.0 L of 1.0 M CH_3COOH. The molar concentration of CH_3COO^- is approximately

A. 0.0
B. 0.5
C. 1.0
D. 2.0

OVER

36. The equation for the reaction of Cl_2O with water is

A. $Cl_2O + H_2O \rightleftarrows 2HClO$
B. $Cl_2O + H_2O \rightleftarrows 2ClO + H_2$
C. $Cl_2O + H_2O \rightleftarrows Cl_2 + H_2O_2$
D. $Cl_2O + H_2O \rightleftarrows Cl_2 + O_2 + H_2$

37. Consider the following redox reaction:

$$2MnO_4^- + 5CH_3CHO + 6H^+ \rightarrow 5CH_3COOH + 2Mn^{2+} + 3H_2O$$

The species that loses electrons is

A. H_2O
B. MnO_4^-
C. CH_3CHO
D. CH_3COOH

38. A spontaneous redox reaction occurs when a piece of iron is placed in 1.0 M $CuSO_4$.
The reducing agent is

A. Fe
B. Cu^{2+}
C. H_2O
D. SO_4^{2-}

39. Consider the following redox reaction:

$$3SO_2 + 3H_2O + ClO_3^- \rightarrow 3SO_4^{2-} + 6H^+ + Cl^-$$

The reduction half-reaction is

A. $ClO_3^- + 6H^+ \rightarrow Cl^- + 3H_2O + 6e^-$
B. $ClO_3^- + 6H^+ + 6e^- \rightarrow Cl^- + 3H_2O$
C. $SO_2 + 2H_2O \rightarrow SO_4^{2-} + 4H^+ + 2e^-$
D. $SO_2 + 2H_2O + 2e^- \rightarrow SO_4^{2-} + 4H^+$

40. Bromine, Br_2, will react spontaneously with

A. I^-
B. I_2
C. Cl^-
D. Cl_2

41. The substances H_2O_2, H_3PO_4 and H_2SO_3 in order of increasing strengths as oxidizing agents are:

A. H_2O_2, H_3PO_4, H_2SO_3
B. H_2SO_3, H_3PO_4, H_2O_2
C. H_3PO_4, H_2SO_3, H_2O_2
D. H_2O_2, H_2SO_3, H_3PO_4

42. The oxidation number of platinum in $Pt(H_2O)_4{}^{2+}$ is

A. +2
B. 0
C. +4
D. $+\frac{1}{2}$

43. Consider the following half-reaction:

$$BrO^- \rightarrow Br^- \quad \text{(basic)}$$

The balanced equation for the half-reaction is

A. $BrO^- + 2H^+ + 2e^- \rightarrow Br^- + H_2O$
B. $BrO^- + 2H^+ \rightarrow Br^- + H_2O + 2e^-$
C. $BrO^- + H_2O \rightarrow Br^- + 2OH^- + 2e^-$
D. $BrO^- + H_2O + 2e^- \rightarrow Br^- + 2OH^-$

OVER

44. In an operating electrochemical cell, the anions migrate

- A. towards the anode through the wire.
- B. towards the cathode through the wire.
- C. towards the anode through the salt bridge.
- D. towards the cathode through the salt bridge.

45. A piece of iron can be prevented from corroding by

- A. making it a cathode.
- B. placing it in an acidic solution.
- C. attaching a small piece of lead to it.
- D. attaching a small piece of gold to it.

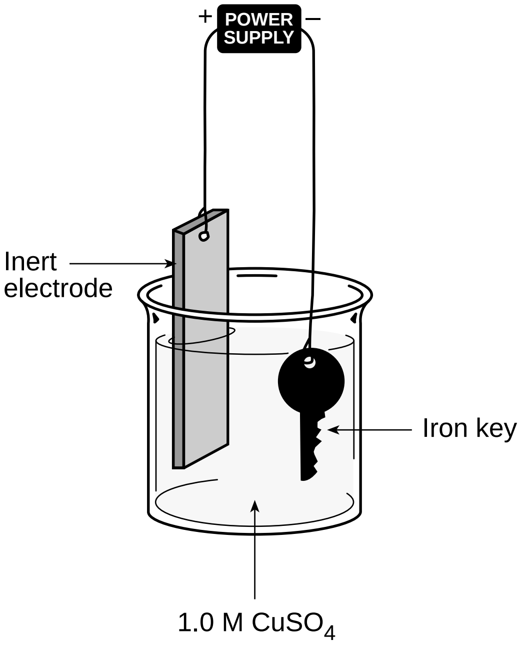
46. Consider the following overall equation for an electrochemical cell:

$$3Ag^+ + Cr \rightarrow Cr^{3+} + 3Ag$$

At standard conditions, the initial cell voltage is

- A. $+0.06$ V
- B. $+0.39$ V
- C. $+1.21$ V
- D. $+1.54$ V

47. Consider the following diagram:



The half-reaction at the cathode is

A. $Cu^{2+} + 2e^- \rightarrow Cu_{(s)}$

B. $2SO_4{}^{2-} \rightarrow S_2O_8{}^{2-} + 2e^-$

C. $H_2O \rightarrow \frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$

D. $2H_2O + 2e^- \rightarrow H_{2(g)} + 2OH^-$

48. An electrolytic process is used to purify impure lead. The electrodes are

	ANODE	CATHODE
A.	carbon	impure lead
B.	pure lead	carbon
C.	pure lead	impure lead
D.	impure lead	pure lead

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. Define the term *activated complex*. **(2 marks)**

Score for Question 1:

1. ______ (2)

2. Using collision theory, explain why a mixture of natural gas and air does not react at room temperature but explodes when a piece of platinum is placed in the gas mixture. **(2 marks)**

Score for Question 2:

2. ______ (2)

3. Identify four characteristics of a chemical equilibrium. **(2 marks)**

i) ______________________________

ii) ______________________________

iii) ______________________________

iv) ______________________________

Score for Question 3:

3. _____ (2)

4. At high temperature, 0.500 mol HBr was placed in a 1.00 L container where it decomposed to give the equilibrium:

$$2\mathrm{HBr}_{(g)} \rightleftarrows \mathrm{H}_{2(g)} + \mathrm{Br}_{2(g)}$$

At equilibrium, the $[\mathrm{Br}_2]$ is $0.0855\ \mathrm{mol/L}$. What is the value of the equilibrium constant? **(3 marks)**

Score for Question 4:

4. _____ (3)

OVER

5. A saturated solution of BaF_2 has a $\left[Ba^{2+}\right]$ of $3.6\times10^{-3}\,M$.
Calculate the K_{sp} value. **(2 marks)**

Score for Question 5:

5. _____
(2)

6. Calculate the maximum mass of Na_2SO_4 which can be dissolved in 2.0 L of 1.5 M $Ca(NO_3)_2$ without a precipitate forming. **(3 marks)**

Score for Question 6:

6. _____
(3)

7. a) Write two equations showing the amphiprotic nature of water as it reacts with HCO_3^-. **(2 marks)**

b) Calculate the K_b for HCO_3^-. **(1 mark)**

Score for Question 7:

7. ______ (3)

8. Calculate the $\left[H_3O^+\right]$ in $0.550\,M\ C_6H_5COOH$. **(3 marks)**

Score for Question 8:

8. ______ (3)

OVER

9. Calculate the pH of the solution formed by mixing 20.0 mL of 0.500 M HCl with 30.0 mL 0.300 M NaOH. **(4 marks)**

Score for Question 9:

9. _____
(4)

10. Consider the following reaction:

$$Cr_2O_7^{2-} + 6Br^- + 14H^+ \rightarrow 2Cr^{3+} + 3Br_2 + 7H_2O$$

In a redox titration, 15.58 mL of 0.125 M $Cr_2O_7^{2-}$ was needed to completely oxidize the Br^- in a 25.00 mL sample of NaBr. Calculate the $\left[Br^-\right]$ in the original solution.
(3 marks)

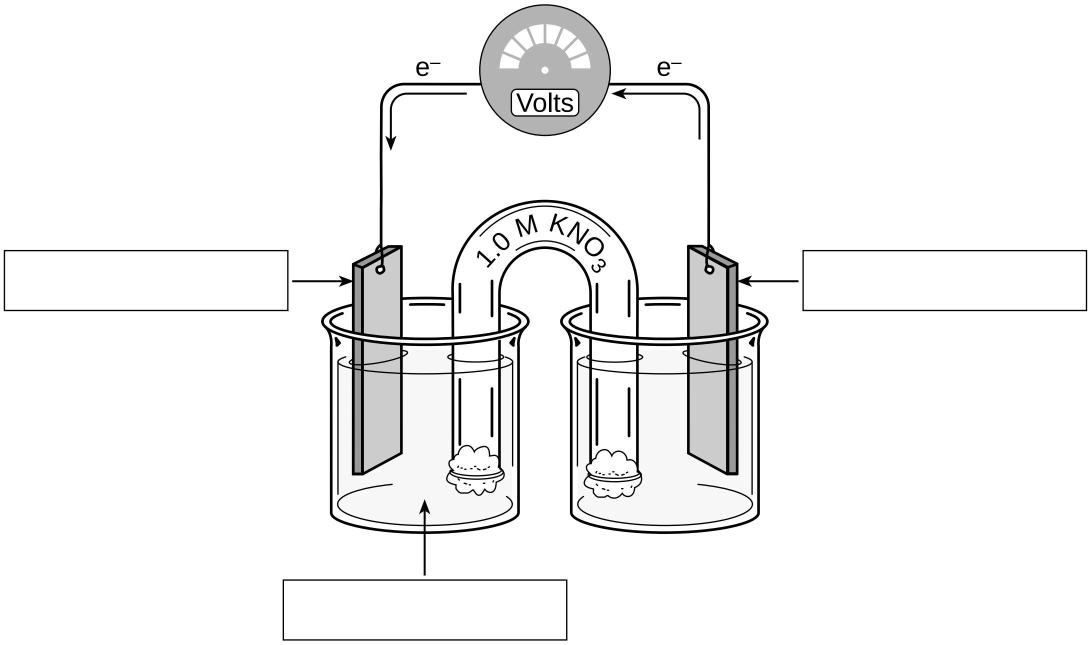
Score for Question 10:

10. _____
(3)

11. Consider the following materials and cell diagram:

- silver, aluminum and nickel electrodes
- 1.0 M solutions of $AgNO_3$, $Al(NO_3)_3$ and $Ni(NO_3)_2$

a) From the above list, select the materials that are capable of producing the greatest voltage, then label the diagram below. **(3 marks)**



b) Calculate the initial voltage for the electrochemical cell in part a). **(1 mark)**

c) Which two metals from the above list would produce an electrochemical cell with the smallest initial voltage? **(1 mark)**

Score for
Question 11:

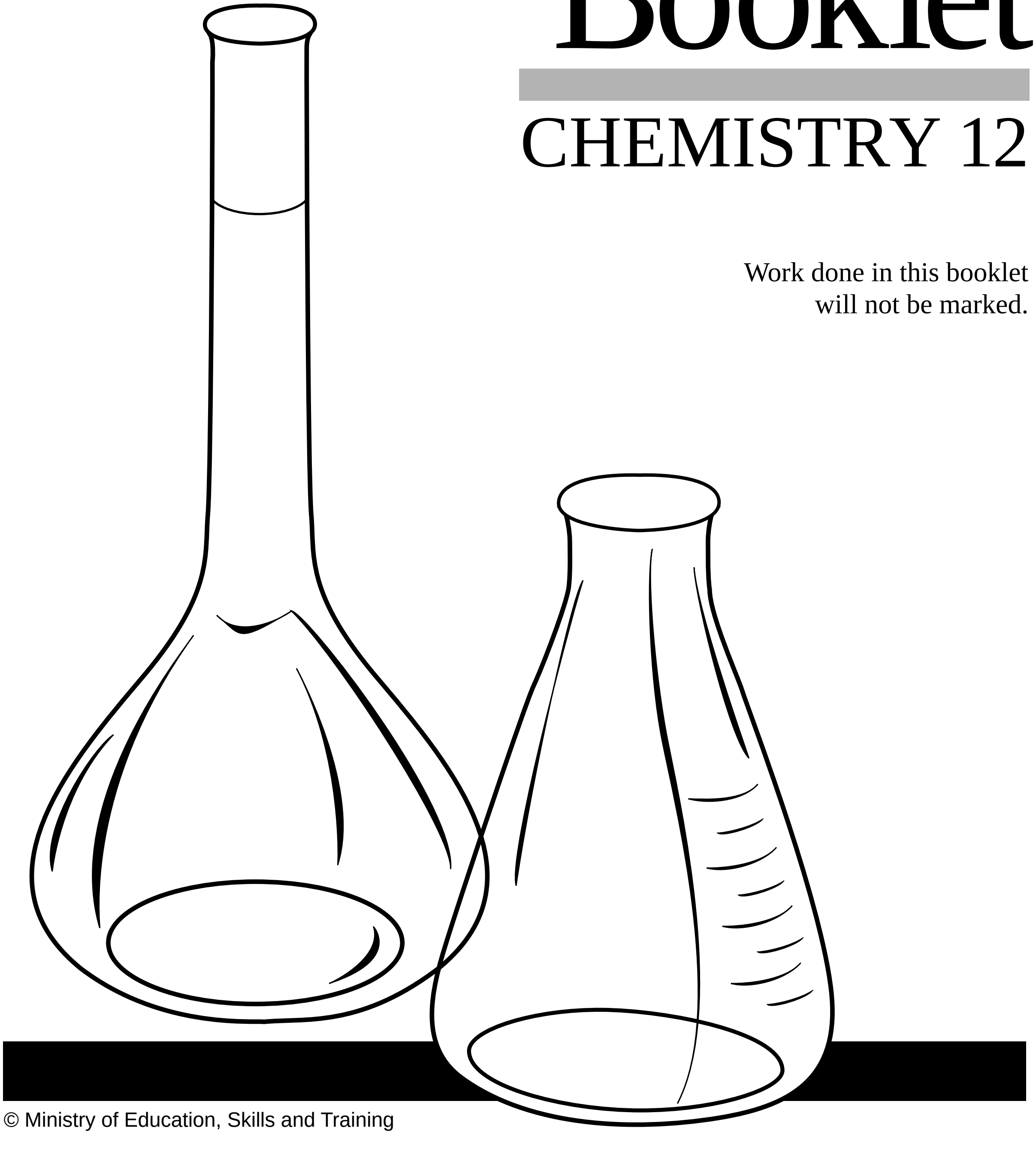
11. _____
(5)

END OF EXAMINATION

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



CONTENTS

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)									

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
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)
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
Hahnium	Ha	105	(262)
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

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+}		
Zinc	Zn^{2+}		

Perchlorate	ClO_4^-
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 > $0.1\ \text{mol/L}$ 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^+	$\rightleftarrows$	$H^+ + H_2O$	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	
Weak						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