INSERT STUDENT I.D. NUMBER (PEN)

STICKER IN THIS SPACE

JUNE 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:	11 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 reactions occurs most rapidly at room temperature?

   A. $H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$

   B. $2Fe_{(s)} + O_{2(g)} \rightarrow 2FeO_{(s)}$

   C. $Cu^{2+}_{(aq)} + S^{2-}_{(aq)} \rightarrow CuS_{(s)}$

   D. $C_6H_{12}O_{6(aq)} + 6O_{2(g)} \rightarrow 6CO_{2(g)} + 6H_2O_{(g)}$

2. Consider the following reaction:

   $$CO + NO_2 \rightarrow CO_2 + NO \qquad \Delta H = -234 \text{ kJ}$$

   The activation energy of the forward reaction is 134 kJ. What is the activation energy for the reverse reaction?

   A. –134 kJ
   B. –100 kJ
   C. 234 kJ
   D. 368 kJ

3. Which of the following will decrease the number of effective collisions during a chemical reaction?

   A. Adding a catalyst.
   B. Increasing the surface area.
   C. Decreasing the temperature.
   D. Increasing reactant concentrations.

OVER

4. Consider the following reaction:

$$2N_2O_{5(g)} + 110\ kJ \rightarrow 4NO_{2(g)} + O_{2(g)}$$

The rate of reaction is increased by

A. adding a catalyst.
B. removing some O_2.
C. decreasing the temperature.
D. increasing the volume of the container.

5. Which of the following apply to all equilibrium systems?

I	Forward and reverse rates are equal
II	Macroscopic properties are constant
III	Mass of reactants equals mass of products

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

6. Consider the following equilibrium:

$$N_{2(g)} + 3H_{2(g)} \rightleftarrows 2NH_{3(g)} + 92\ kJ$$

The forward reaction is

A. exothermic and entropy is increasing.
B. exothermic and entropy is decreasing.
C. endothermic and entropy is increasing.
D. endothermic and entropy is decreasing.

7. Consider the following equilibrium:

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

The equilibrium concentration of PCl_5 will increase when

A. PCl_3 is added.
B. Cl_2 is removed.
C. a catalyst is added.
D. the volume of the container is increased.

8. Consider the following equilibrium:

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

If the volume of the container is decreased, the

A. K_{eq} decreases.
B. $[N_2O_4]$ increases.
C. equilibrium does not shift.
D. equilibrium shifts to the right.

9. Consider the following equilibrium:

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

For this reaction,

A. $K_{eq} = [CO_2]$

B. $K_{eq} = \dfrac{1}{[CO_2]}$

C. $K_{eq} = \dfrac{[CaCO_3]}{[CO_2][CaO]}$

D. $K_{eq} = \dfrac{[CO_2][CaO]}{[CaCO_3]}$

OVER

10. Which of the following reactions most favours products?

	REACTION	K_{eq}
I	$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)}$	2.6×10^{2}
II	$2NO_{(g)} + O_{2(g)} \rightleftarrows 2NO_{2(g)}$	6.4×10^{5}
III	$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}$	2.5×10^{15}
IV	$2H_{2(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)}$	1.7×10^{27}

A. I
B. II
C. III
D. IV

11. Consider the following:

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

At equilibrium in a 1.0 L container, there are 1.60×10^{-2} mol C, 1.50×10^{-2} mol H_2O, 3.00×10^{-1} mol CO, and 1.00×10^{-1} mol H_2. The value of K_{eq} is

A. 0.500
B. 2.00
C. 80.0
D. 125

12. Consider the following equilibrium:

$$N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 1.0 \times 10^{-2}$$

At equilibrium, the $[NO_2] = 2.0 \times 10^{-2}$ mol/L and the $[N_2O_4]$ is

A. 4.0×10^{-6} mol/L

B. 4.0×10^{-2} mol/L

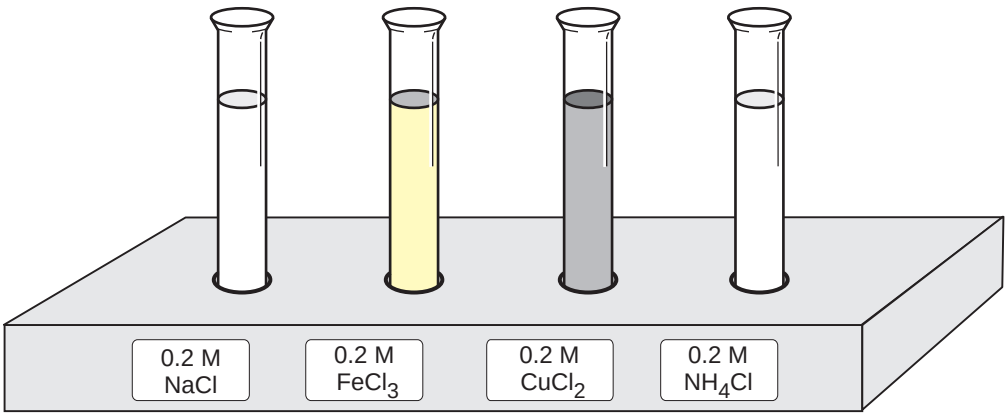
C. 2.0 mol/L

D. 25 mol/L

13. Which of the following dissolves in water to form an ionic solution?

A. O_2
B. SiO_2
C. $KMnO_4$
D. $C_{12}H_{22}O_{11}$

14. A dilute solution of $AgNO_3$ is added dropwise to each of the following test tubes until a precipitate forms in each tube.



Which solution requires the lowest $\left[Ag^+\right]$ to just begin precipitation?

A. NaCl
B. $FeCl_3$
C. $CuCl_2$
D. NH_4Cl

15. Which of the following is most soluble?

A. Na_2S
B. $CaSO_4$
C. $PbCO_3$
D. $Zn(OH)_2$

OVER

16. The solubility of PbI_2 will increase with the addition of

A. PbI_2

B. heat.

C. water.

D. $Pb(NO_3)_2$

17. Which of the following saturated solutions has the lowest $\left[SO_4^{2-}\right]$ at $25°\,C$?

A. $SrSO_4$

B. $PbSO_4$

C. $CaSO_4$

D. $BaSO_4$

18. The solubility of $MgCO_3$ is

A. 4.6×10^{-11} M

B. 6.8×10^{-6} M

C. 1.4×10^{-5} M

D. 2.6×10^{-3} M

19. When equal volumes of 0.20 M $Pb(NO_3)_2$ and 0.20 M KI are mixed together,

A. a precipitate forms since Trial Ion Product > K_{sp}

B. a precipitate forms since Trial Ion Product < K_{sp}

C. no precipitate forms since Trial Ion Product > K_{sp}

D. no precipitate forms since Trial Ion Product < K_{sp}

20. Bubbles form when $Mg_{(s)}$ is added to $HCl_{(aq)}$. The gas produced is

A. O_2

B. H_2

C. Cl_2

D. H_2O

21. *A substance which produces hydrogen ions in solution* is the definition of

A. an Arrhenius acid.
B. an Arrhenius base.
C. a Brönsted-Lowry acid.
D. a Brönsted-Lowry base.

22. The number of conjugate pairs in a Brönsted-Lowry acid-base equation is

A. 1
B. 2
C. 3
D. 4

23. Which of the following is a stronger base than HPO_4^{2-} ?

A. H_2O
B. NO_2^-
C. CO_3^{2-}
D. $H_2PO_4^-$

24. Consider the following equilibria:

$$HTe^- + HSe^- \rightleftarrows H_2Te + Se^{2-}$$

$$HTe^- + Se^{2-} \rightleftarrows HSe^- + Te^{2-}$$

Reactants are favoured in both equilibria. The order of acids from strongest to weakest is

A. $HTe^-,\ HSe^-,\ H_2Te$
B. $HSe^-,\ H_2Te,\ HTe^-$
C. $H_2Te,\ HTe^-,\ HSe^-$
D. $H_2Te,\ HSe^-,\ HTe^-$

OVER

25. The equilibrium expression for the ion product constant of water is

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

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

C. $K_w = \dfrac{\left[H_2O\right]^2}{\left[H_3O^+\right]\left[OH^-\right]}$

D. $K_w = \dfrac{\left[H_3O^+\right]\left[OH^-\right]}{\left[H_2O\right]^2}$

26. Calculate the pH of 0.01 M NaOH.

A. 1.0×10^{-12}
B. 1.0×10^{-2}
C. 2.0
D. 12.0

27. Consider the following:

TEMPERATURE	K_w
$25°C$	1.0×10^{-14}
$50°C$	5.5×10^{-14}

When water is heated,

A. $\left[H_3O^+\right]$ and $\left[OH^-\right]$ both increase.
B. $\left[H_3O^+\right]$ and $\left[OH^-\right]$ both decrease.
C. $\left[H_3O^+\right]$ increases and $\left[OH^-\right]$ decreases.
D. $\left[H_3O^+\right]$ decreases and $\left[OH^-\right]$ increases.

28. The $\left[H_3O^+\right]$ of a solution with a pOH of 4.60 is

A. 4.0×10^{-10} M
B. 2.5×10^{-5} M
C. 6.6×10^{-1} M
D. 9.7×10^{-1} M

29. The K_b expression for aniline, $C_6H_5NH_2$, is

A. $K_b = \left[C_6H_5NH_3{}^+\right]\left[OH^-\right]$

B. $K_b = \left[\ C_6H_5NH^-\right]\left[H_3O^+\right]$

C. $K_b = \dfrac{\left[C_6H_5NH_3{}^+\right]\left[OH^-\right]}{\left[C_6H_5NH_2\right]}$

D. $K_b = \dfrac{\left[\ C_6H_5NH^-\right]\left[H_3O^+\right]}{\left[C_6H_5NH_2\right]}$

30. A solution of 0.10 M $HPO_4{}^{2-}$ is

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

31. Consider the following equilibrium:

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

At the transition point for an acid-base indicator,

A. $K_a = \left[Ind^-\right]$
B. $K_a = [HInd]$
C. $K_a = \left[H_3O^+\right]$
D. $K_a = \left[H_3O^+\right]\left[OH^-\right]$

OVER

32. A solution is amber with neutral red and colourless with phenolphthalein. The approximate pH of the solution is

A. 4
B. 6
C. 8
D. 10

33. When a 1.0 M acidic solution is titrated with a 1.0 M basic solution, the pH at the equivalence point is 8.5. The reactants could be

A. HBr and KOH
B. HNO_3 and NH_3
C. HCl and NaOH
D. HNO_2 and NaOH

34. The net ionic equation for the reaction between $KOH_{(aq)}$ and $HBr_{(aq)}$ is

A. $K^+_{(aq)} + Br^-_{(aq)} \rightarrow KBr_{(s)}$
B. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)}$
C. $KOH_{(aq)} + HBr_{(aq)} \rightarrow KBr_{(aq)} + H_2O_{(\ell)}$
D. $K^+_{(aq)} + OH^-_{(aq)} + H^+_{(aq)} + Br^-_{(aq)} \rightarrow K^+_{(aq)} + Br^-_{(aq)} + H_2O_{(\ell)}$

35. Consider the following equilibrium for a buffer solution:

$$CH_3COOH + H_2O \rightleftarrows CH_3COO^- + H_3O^+$$

When a small amount of acid is added to this system, and equilibrium is reestablished,

A. $\left[CH_3COO^-\right]$ and pH have both increased.
B. $\left[CH_3COOH\right]$ and pH have both decreased.
C. $\left[CH_3COO^-\right]$ has decreased and pH remains relatively constant.
D. $\left[CH_3COOH\right]$ has decreased and pH remains relatively constant.

36. Which of the following dissolves in water to form a basic solution?

A. NO
B. SO_3
C. CO_2
D. K_2O

37. Which of the following is an equation representing a redox reaction?

A. $2NO_{2(g)} \rightarrow N_2O_{4(g)}$
B. $Mg_{(s)} + Cl_{2(g)} \rightarrow MgCl_{2(s)}$
C. $Ag^+{}_{(aq)} + Cl^-{}_{(aq)} \rightarrow AgCl_{(s)}$
D. $NH_{3(aq)} + H^+{}_{(aq)} \rightarrow NH_4{}^+{}_{(aq)}$

38. Consider the following:

$$O_3 + H_2O + SO_2 \rightarrow SO_4{}^{2-} + O_2 + 2H^+$$

In the redox reaction above, the chemical species oxidized is

A. H^+
B. O_3
C. SO_2
D. $SO_4{}^{2-}$

39. A product of the oxidation of NO_2 is

A. NO
B. N_2O
C. $NO_2{}^-$
D. $NO_3{}^-$

OVER

40. Which of the following is the strongest reducing agent?

A. Sn^{2+}
B. Fe^{2+}
C. Au^{3+}
D. Mn^{2+}

41. At standard conditions, a spontaneous reaction will occur between

A. Pb and Fe^{2+}
B. Cu and Sn^{2+}
C. Cu^{2+} and Sn^{2+}
D. Pb^{2+} and Fe^{2+}

42. Consider the following:

$$2MnO_4^- + 5H_2O_2 + 6H^+ \rightarrow 5O_2 + 2Mn^{2+} + 8H_2O$$

In an experiment, 2.00×10^{-4} mol of MnO_4^- is required to titrate 10.0 mL of H_2O_2 to the equivalence point. The concentration of H_2O_2 is

A. 5.00×10^{-3} M
B. 8.00×10^{-3} M
C. 2.00×10^{-2} M
D. 5.00×10^{-2} M

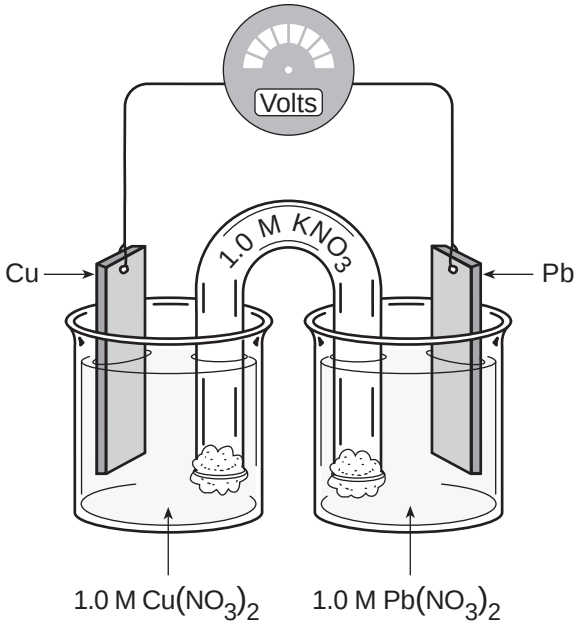
43. A lead storage battery contains electrochemical cells which involve the following half-reactions:

$$PbO_2 + 4H^+ + SO_4^{2-} + 2e^- \rightleftarrows PbSO_4 + 2H_2O \qquad E° = +1.69 \text{ V}$$
$$PbSO_4 + 2e^- \rightleftarrows Pb + SO_4^{2-} \qquad E° = -0.36 \text{ V}$$

Use the data above to calculate the $E°$ for one of these cells.

A. $E° = +1.33$ V
B. $E° = -1.33$ V
C. $E° = -2.05$ V
D. $E° = +2.05$ V

Use the following diagram to answer questions 44, 45 and 46.



44. In the electrochemical cell above, the half-reaction at the cathode is

A. $Pb \rightarrow Pb^{2+} + 2e^-$

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

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

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

45. In the electrochemical cell above, the anode

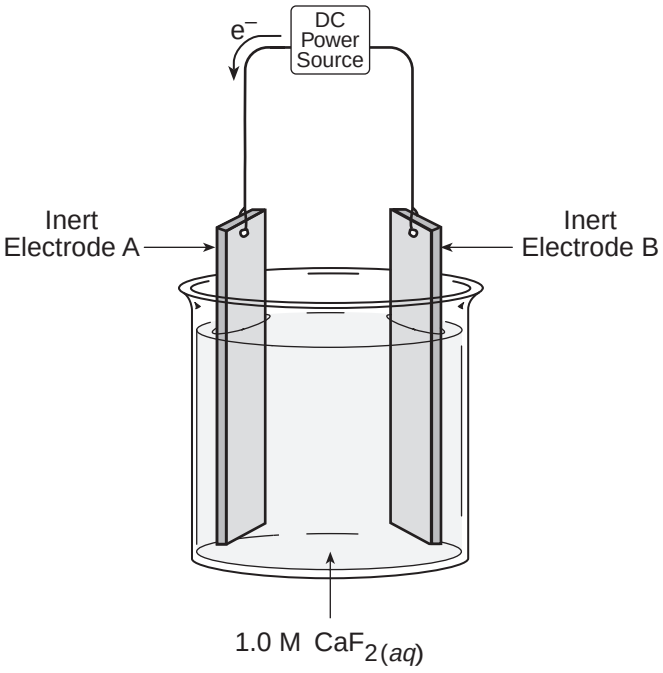
A. loses mass as Pb is oxidized.
B. gains mass as Pb is oxidized.
C. loses mass as Cu is oxidized.
D. gains mass as Cu is oxidized.

46. In the salt bridge in the electrochemical cell above,

A. electrons flow into the Pb half-cell.
B. electrons flow into the Cu half-cell.
C. anions migrate into the Pb half-cell.
D. anions migrate into the Cu half-cell.

OVER

Use the following diagram to answer questions 47 and 48.



47. The predominant half-reaction occurring at Electrode B is

A. $2F^- \rightarrow F_2 + 2e^-$

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

C. $2H_2O \rightarrow O_2 + 4H^+ + 4e^-$

D. $2H_2O + 2e^- \rightarrow H_2 + 2OH^-$

48. In the electrolytic cell above, a suitable substance for Electrode B is

A. carbon.
B. lithium.
C. sodium.
D. calcium.

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

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. A reaction does not always occur when two reactant particles collide. Give **two** reasons why. **(2 marks)**

   i) _____

   _____

   ii) _____

   _____

2. Consider the following reaction mechanism:

   Step 1: $NO + NO \rightarrow N_2O_2$

   Step 2: $N_2O_2 + H_2 \rightarrow N_2O + H_2O$

   Step 3: $N_2O + H_2 \rightarrow N_2 + H_2O$

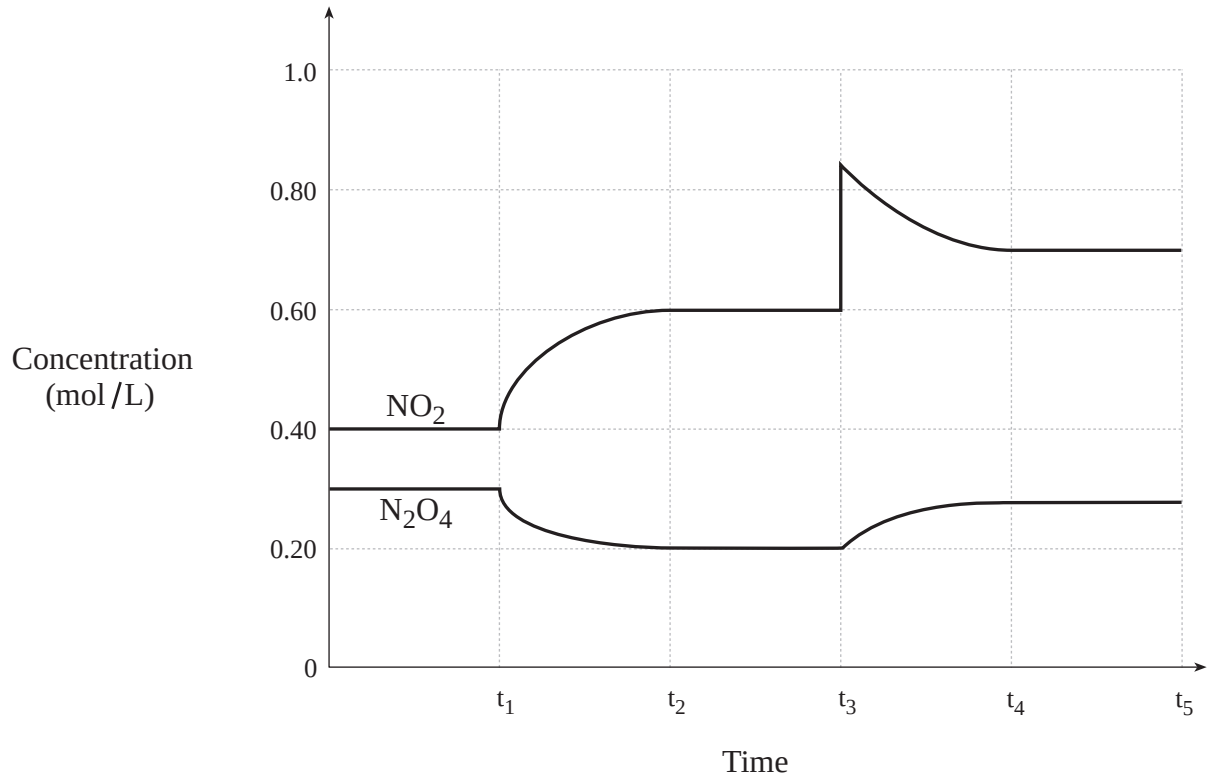
   a) Write the equation for the overall reaction. **(1 mark)**

   b) Identify the reaction intermediate(s). **(1 mark)**

OVER

3. Consider the following graph for the reaction:

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



a) What is the stress imposed at time t_1 ? **(1 mark)**

b) What is the stress imposed at time t_3 ? **(1 mark)**

c) Calculate K_{eq} for the equilibrium between t_2 and t_3. **(2 marks)**

4. Consider the following net ionic equation:

$$Ag^{+}_{(aq)} + SCN^{-}_{(aq)} \rightarrow AgSCN_{(s)}$$

A 20.00 mL sample of 0.200 M NH_4SCN is used to titrate a 30.00 mL sample containing Ag^{+}. Calculate the $\left[Ag^{+}\right]$ in the original sample. **(3 marks)**

OVER

5. A solution contains 0.020 M Ba^{2+} and an unknown concentration of Sr^{2+}. When dilute Na_2CO_3 is slowly added to the mixture, both Ba^{2+} and Sr^{2+} start to precipitate at the same time. **(3 marks)**

a) Calculate the $\left[CO_3^{2-}\right]$ when $BaCO_3$ starts to precipitate.

b) Calculate the initial $\left[Sr^{2+}\right]$.

6. a) Define the term *amphiprotic*. **(1 mark)**

b) Give an example of an amphiprotic anion. **(1 mark)**

7. The salt Na_2CO_3 undergoes hydrolysis to produce a basic solution. Calculate the $\left[OH^-\right]$ in 0.100 M Na_2CO_3. **(4 marks)**

OVER

8. A student titrated a 25.00 mL sample of a 0.20 M HX (unknown) acid with 0.20 M NaOH. The following data were collected.

Volume of base added (mL)	pH
0.00	2.72
10.00	4.57
24.90	7.14
24.99	8.14
25.00	8.88
25.01	9.60
26.00	11.59
35.00	12.52

a) Describe the acid HX as strong or weak. Support your answer with two observations from the data table. **(3 marks)**

b) Select an appropriate indicator for this titration and identify the colour at the equivalence point. **(1 mark)**

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

$$Ni + ClO_4^- \rightarrow Ni^{2+} + Cl^- \quad \text{(acid)}$$

10. Define the term *electrolysis*. **(2 marks)**

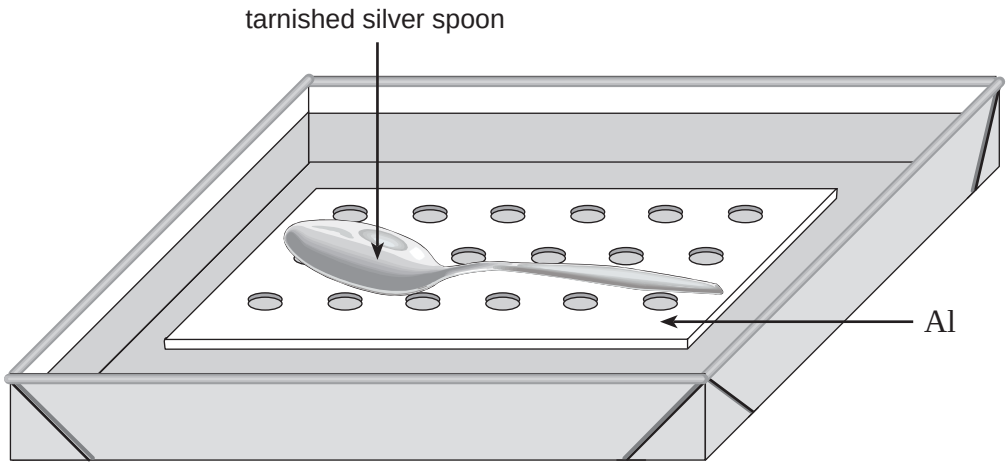
_____

_____

_____

OVER

11. Consider the following diagram:



On a silver spoon, the black tarnish, Ag_2S, can be removed spontaneously by placing the spoon in contact with aluminum in a conducting solution.

a) Write the equations for the two half-reactions. **(2 marks)**

b) Write the equation for the redox reaction. **(1 mark)**

END OF EXAMINATION

INSERT STUDENT I.D. NUMBER (PEN)

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CHEMISTRY 12

June 1998

Course Code = CH

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CHEMISTRY 12

June 1998

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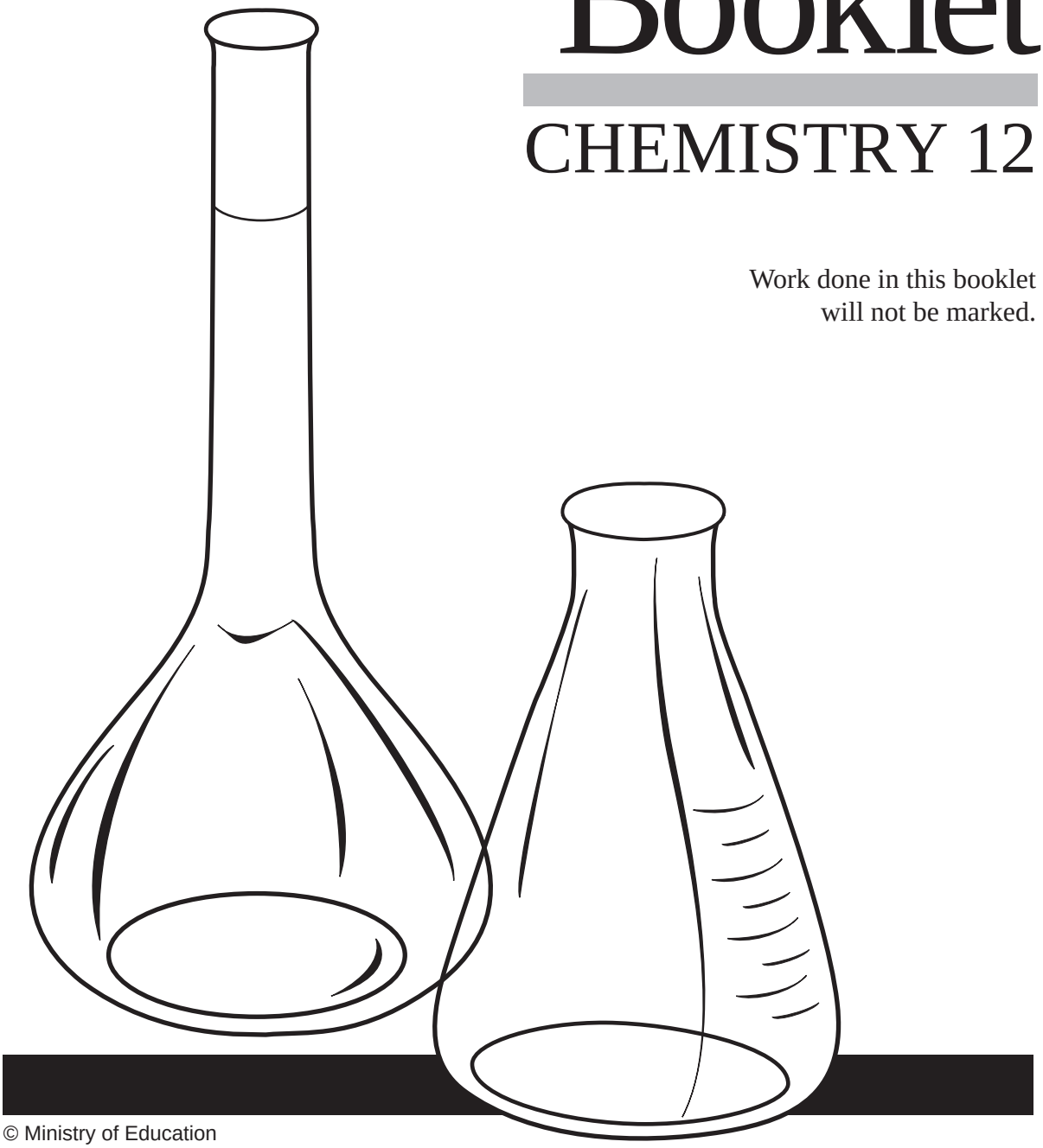
Score for Question 1: 1. _____ (2)	Score for Question 8: 8. _____ (4)
Score for Question 2: 2. _____ (2)	Score for Question 9: 9. _____ (3)
Score for Question 3: 3. _____ (4)	Score for Question 10: 10. _____ (2)
Score for Question 4: 4. _____ (3)	Score for Question 11: 11. _____ (3)
Score for Question 5: 5. _____ (3)	
Score for Question 6: 6. _____ (2)	
Score for Question 7: 7. _____ (4)	

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



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CONTENTS

REFERENCE

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

PERIODIC TABLE OF THE ELEMENTS

1												13	14	15	16	17	18
1 H Hydrogen 1.0	2																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	3	4	5	6	7	8	9	10	11	12	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)									

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
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)	
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 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

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	
	$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+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	
	$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−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

Overpotential Effect

Overpotential Effect