MINISTRY USE ONLY

MINISTRY USE ONLY

Place Personal Education Number (PEN) here.

Place Personal Education Number (PEN) here.

MINISTRY USE ONLY

BRITISH COLUMBIA

Chemistry 12

AUGUST 2001

Course Code = CH

Student Instructions

1. Place the stickers with your Personal Education Number (PEN) in the allotted spaces above. **Under no circumstance is your name or identification, other than your Personal Education Number, to appear on this booklet.**
2. Ensure that in addition to this examination booklet, you have a **Data Booklet** and an **Examination Response Form**. Follow the directions on the front of the Response Form.
3. **Disqualification** from the examination will result if you bring books, paper, notes or unauthorized electronic devices into the examination room.
4. When instructed to open this booklet, **check the numbering of the pages** to ensure that they are numbered in sequence from page one to the last page, which is identified by

   END OF EXAMINATION.

5. At the end of the examination, place your Response Form inside the front cover of this booklet and return the booklet and your Response Form to the supervisor.

Question 1:

1. . .

(4)

Question 7:

7. . .

(4)

Question 2:

2. . .

(3)

Question 8:

8. . .

(4)

Question 3:

3. . .

(4)

Question 9:

9. . .

(3)

Question 4:

4. . .

(3)

Question 10:

10. . .

(6)

Question 5:

5. . .

(3)

Question 11:

11. . .

(4)

Question 6:

6. . .

(2)

CHEMISTRY 12

AUGUST 2001

COURSE CODE = CH

GENERAL INSTRUCTIONS

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

2. All multiple-choice answers must be entered on the Response Form using an **HB pencil**. Multiple-choice answers entered in this examination booklet will **not** be marked.

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

4. Ensure that you use language and content appropriate to the purpose and audience of this examination. Failure to comply may result in your paper being awarded a zero.

5. This examination is designed to be completed in **two hours**. *Students may, however, take up to 30 minutes of additional time to finish*.

CHEMISTRY 12 PROVINCIAL EXAMINATION

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

	Value	Suggested Time
PART A: 48 multiple-choice questions	60	70
PART B: 11 written-response questions	40	50
Total:	**100 marks**	**120 minutes**

2. The following tables can be found in the separate **Data Booklet**.
   - Periodic Table of the Elements
   - Atomic Masses of the Elements
   - Names, Formulae, and Charges of Some Common Ions
   - Solubility of Common Compounds in Water
   - Solubility Product Constants at 25° C
   - Relative Strengths of Brønsted-Lowry Acids and Bases
   - Acid-Base Indicators
   - Standard Reduction Potentials of Half-cells

   No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions and may also include graphing functions. Computers, calculators with a QWERTY keyboard, and electronic writing pads will not be allowed. Students must not bring any external devices to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, or external keyboards. Students may have more than one calculator available during the examination. Calculators may not be shared and must not have the ability to either transmit or receive electronic signals. In addition to an approved calculator, students will be allowed to use rulers, compasses, and protractors during the examination.

THIS PAGE INTENTIONALLY BLANK

PART A: MULTIPLE CHOICE

Value: 60 marks **Suggested Time: 70 minutes**

INSTRUCTIONS: For each question, select the **best** answer and record your choice on the Response Form provided. Using an HB pencil, completely fill in the circle that has the letter corresponding to your answer.

Selected multiple-choice questions are worth 2 marks.

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

$$N_2H_{4(\ell)} + 2H_2O_{2(\ell)} \rightarrow N_{2(g)} + 4H_2O_{(\ell)}$$

In 5.0 seconds, 0.015 mol of H_2O_2 is consumed. The rate of production of N_2 is

A. 1.5×10^{-3} mol/s
B. 3.0×10^{-3} mol/s
C. 6.0×10^{-3} mol/s
D. 1.5×10^{-2} mol/s

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

$$3Fe_2O_{3(s)} + CO_{(g)} \rightarrow 2Fe_3O_{4(s)} + CO_{2(g)} + 46\,kJ$$

Which of the following would cause the rate of the reaction to increase?

A. removing the Fe_3O_4
B. decreasing the temperature
C. increasing the surface area of Fe_2O_3
D. increasing the volume of the reaction vessel

3. *Activation energy* is described as **(1 mark)**

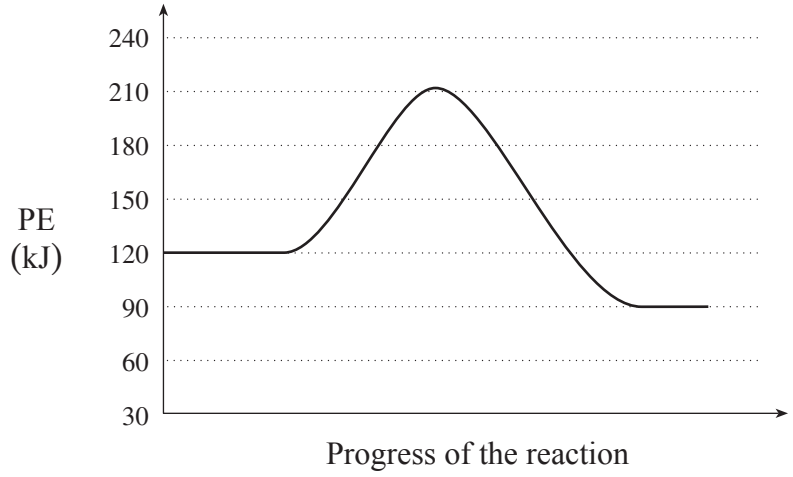
A. the energy of the activated complex.
B. a point on the PE diagram where KE = PE.
C. the unstable high PE structural arrangement of atoms.
D. the minimum PE difference between the activated complex and the reactants.

OVER

4. What happens to the activation energy and ΔH when a catalyst is added to a reaction? **(2 marks)**

	Activation Energy	ΔH
A.	increases	remains the same
B.	increases	increases
C.	decreases	remains the same
D.	decreases	decreases

5. Consider the following potential energy diagram for a reaction: **(1 mark)**



What is the value of ΔH for this reaction?

A. −120 kJ
B. −30 kJ
C. +30 kJ
D. +120 kJ

6. A substance that is produced in one step in a reaction mechanism and consumed in a subsequent step, without appearing in the overall reaction, is a(n) **(1 mark)**

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

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

A. $K_{eq} = 1$
B. [reactants] = [products].
C. rate forward = rate reverse.
D. mass of reactants = mass of products.

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

$$4HCl_{(g)} + O_{2(g)} \rightleftarrows 2H_2O_{(g)} + 2Cl_{2(g)} + 111.4\,kJ$$

For the forward reaction, how do enthalpy and entropy change?

	Enthalpy	Entropy
A.	increases	decreases
B.	decreases	decreases
C.	increases	increases
D.	decreases	increases

OVER

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

$$CH_3Cl_{(aq)} + OH^-_{(aq)} \rightleftarrows CH_3OH_{(aq)} + Cl^-_{(aq)}$$

The equilibrium will shift to the left as a result of the addition of

A. HNO_3

B. KNO_3

C. NaOH

D. CH_3Cl

10. Consider the following equilibrium at 25°C : **(1 mark)**

$$Ni_{(s)} + 4CO_{(g)} \rightleftarrows Ni(CO)_{4(\ell)}$$

For this reaction

A. $K_{eq} = [CO]^4$

B. $K_{eq} = \dfrac{1}{[CO]^4}$

C. $K_{eq} = \dfrac{[Ni(CO)_4]}{[CO]^4\,[Ni]}$

D. $K_{eq} = \dfrac{[Ni(CO)_4]}{[CO]^4}$

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

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

At equilibrium, $[CO_2] = 0.050\ \text{mol/L}$ and $[CF_4] = 0.050\ \text{mol/L}$.
What is $[COF_2]$ at equilibrium?

A. 0.0012 mol/L
B. 0.035 mol/L
C. 0.050 mol/L
D. 0.22 mol/L

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

$$H_2O_{(g)} + Cl_2O_{(g)} \rightleftarrows 2HOCl_{(g)} \qquad K_{eq} = 0.0900$$

Initially, a 1.00 L flask is filled with 0.100 mol of H_2O, 0.100 mol of Cl_2O and 0.100 mol of HOCl. As equilibrium is established, the reaction proceeds to the

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

13. At 25°C, which of the following compounds has a low solubility when added to water? **(1 mark)**

A. FeS
B. $CuCl_2$
C. $ZnSO_4$
D. NH_4CH_3COO

OVER

14. Which of the following forms a molecular solution? **(1 mark)**

A. KCl
B. NaOH
C. CH_3OH
D. NH_4CH_3COO

15. List the compounds AgI, KBr and $MgCO_3$ in order of solubility from lowest to highest. **(2 marks)**

A. AgI, $MgCO_3$, KBr
B. KBr, AgI, $MgCO_3$
C. KBr, $MgCO_3$, AgI
D. $MgCO_3$, AgI, KBr

16. Consider the following K_{sp} expression: **(1 mark)**

$$K_{sp} = \left[Cu^{2+}\right]\left[IO_3^{-}\right]^2$$

Which of the following does this equilibrium expression represent?

A. $CuIO_{3(s)} \rightleftarrows Cu^{+}_{(aq)} + IO_3^{-}{}_{(aq)}$
B. $CuIO_{3(s)} \rightleftarrows Cu^{2+}_{(aq)} + IO_3^{2-}{}_{(aq)}$
C. $CuIO_{3(s)} \rightleftarrows Cu^{2+}_{(aq)} + IO_3^{-}{}_{(aq)}$
D. $Cu(IO_3)_{2(s)} \rightleftarrows Cu^{2+}_{(aq)} + 2IO_3^{-}{}_{(aq)}$

17. The solubility of $NiCO_3$ is 3.8×10^{-4} mol/L. The K_{sp} value is **(1 mark)**

A. 1.4×10^{-7}
B. 3.8×10^{-4}
C. 7.6×10^{-4}
D. 1.9×10^{-2}

18. The $\left[Ag^{+}\right]$ in a saturated solution of $AgBrO_3$ is **(1 mark)**

A. 2.8×10^{-9} M
B. 2.6×10^{-5} M
C. 5.3×10^{-5} M
D. 7.3×10^{-3} M

19. When solutions of $AgNO_3$ and NaCl are combined, the Trial K_{sp} for AgCl is 5.6×10^{-11}. Predict what will be observed. **(2 marks)**

A. a precipitate will form because Trial $K_{sp} < K_{sp}$
B. a precipitate will form because Trial $K_{sp} > K_{sp}$
C. a precipitate will not form because Trial $K_{sp} < K_{sp}$
D. a precipitate will not form because Trial $K_{sp} > K_{sp}$

20. Calculate the maximum $\left[CO_3^{2-}\right]$ that can exist in a solution without forming a precipitate when $\left[Mg^{2+}\right] = 0.20\,M$. **(1 mark)**

A. 1.4×10^{-6} M
B. 3.4×10^{-5} M
C. 2.6×10^{-3} M
D. 5.8×10^{-3} M

21. Which of the following reactions is not a neutralization reaction? **(1 mark)**

A. $KOH + HF \rightarrow KF + H_2O$
B. $CH_4 + 2\,O_2 \rightarrow CO_2 + 2H_2O$
C. $Ca(OH)_2 + 2HCl \rightarrow CaCl_2 + 2H_2O$
D. $Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$

OVER

22. What is the conjugate acid and what is the conjugate base of HPO_4^{2-} ? **(2 marks)**

	Conjugate Acid	Conjugate Base
A.	PO_4^{3-}	$H_2PO_4^-$
B.	$H_2PO_4^-$	PO_4^{3-}
C.	$H_2PO_4^-$	H_3PO_4
D.	H_3PO_4	PO_4^{3-}

23. Which of the following would be the same when comparing equal volumes of 1.0 M HBr and 1.0 M CH_3COOH? **(1 mark)**

A. the pH
B. the electrical conductivity
C. the titration curve for reaction with a base
D. the moles of base required for neutralization

24. Which of the following represents the predominant reaction between NH_3 and H_2O ? **(1 mark)**

A. $NH_3 + H_2O \rightleftarrows NH_3O + H_2$

B. $NH_3 + H_2O \rightleftarrows NH_4^+ + OH^-$

C. $NH_3 + H_2O \rightleftarrows NH_5^{2+} + O^{2-}$

D. $NH_3 + H_2O \rightleftarrows H_3O^+ + NH_2^-$

25. Consider the following reaction: **(2 marks)**

$$HPO_4^{2-} + H_2SO_3 \rightleftarrows H_2PO_4^- + HSO_3^-$$

What is the strongest acid and strongest base in the above system?

	Strongest acid	Strongest base
A.	$H_2PO_4^-$	HSO_3^-
B.	$H_2PO_4^-$	HPO_4^{2-}
C.	H_2SO_3	HSO_3^-
D.	H_2SO_3	HPO_4^{2-}

26. When a solution has pOH = 5.30, the $\left[OH^-\right]$ is **(1 mark)**

A. 5.0×10^{-6} M
B. 2.0×10^{-9} M
C. 0.72 M
D. 13.27 M

27. How many moles of HI are needed to prepare 3.0 L of an HI solution with a pH of 1.00? **(1 mark)**

A. 0.030 mol
B. 0.30 mol
C. 3.0 mol
D. 30 mol

28. Which of the following 1.0×10^{-3} M solutions has a pH of 3.0? **(1 mark)**

A. HCl
B. HCN
C. NaOH
D. K_2SO_4

OVER

29. Which of the following expressions shows the relationship between K_a and K_b for a conjugate pair? **(1 mark)**

A. $K_a \times K_b = 14$
B. $K_a + K_b = 14$
C. $K_a \times K_b = K_w$
D. $K_a \div K_b = K_w$

30. Which of the following will be the most basic? **(1 mark)**

A. 1.0 M NO_3^-
B. 1.0 M SO_4^{2-}
C. 1.0 M CO_3^{2-}
D. 1.0 M PO_4^{3-}

31. Dissolving $NaCH_3COO$ in water will produce a solution which is **(2 marks)**

A. basic with pH > 7
B. basic with pH < 7
C. acidic with pH > 7
D. acidic with pH < 7

32. Which would produce a yellow solution at a pH = 4.0 ? **(1 mark)**

A. methyl red
B. methyl violet
C. indigo carmine
D. chlorophenol red

33. How many moles of NaOH are required to react completely with 100.0 mL of 2.5 M HNO_3 ? **(1 mark)**

A. 0.0063 mol
B. 0.25 mol
C. 2.5 mol
D. 250 mol

34. The net ionic equation for the reaction between HCl and KOH is **(1 mark)**

A. $H^+ + OH^- \rightleftarrows H_2O$
B. $HCl + KOH \rightleftarrows H_2O + KCl$
C. $H^+ + Cl^- + K^+ + OH^- \rightleftarrows H_2O + KCl$
D. $H^+ + Cl^- + K^+ + OH^- \rightleftarrows H_2O + K^+ + Cl^-$

35. Which of the following titrations would have a pH > 7 at the equivalence point? **(1 mark)**

A. HI with KOH
B. $HClO_4$ with NH_3
C. HCl with $Sr(OH)_2$
D. HCOOH with NaOH

36. A buffer can be made from equal moles of **(2 marks)**

A. HCl and NaCl
B. HCN and KOH
C. HNO_3 and NH_3
D. CH_3COOH and $NaCH_3COO$

37. Which of the following dissolves in water to produce a basic solution? **(1 mark)**

A. O_2
B. SO_2
C. NO_2
D. MgO

OVER

38. Consider the following spontaneous reaction: **(1 mark)**

$$2Al_{(s)} + 3Cu^{2+}_{(aq)} \rightarrow 2Al^{3+}_{(aq)} + 3Cu_{(s)}$$

In this reaction, the oxidizing agent is

A. Al
B. Cu
C. Al^{3+}
D. Cu^{2+}

39. Bromine has an oxidation number of +3 in **(1 mark)**

A. KBrO
B. $KBrO_2$
C. $KBrO_3$
D. $KBrO_4$

40. In an experiment, Te reacts spontaneously with Ag^+ but not with Ti^{2+}.
The relative strength of oxidizing agents from strongest to weakest is **(2 marks)**

A. $Ag^+ > Te^{4+} > Ti^{2+}$
B. $Ag^+ > Ti^{2+} > Te^{4+}$
C. $Te^{4+} > Ti^{2+} > Ag^+$
D. $Ti^{2+} > Te^{4+} > Ag^+$

41. A piece of Au does not react spontaneously with 1.0 M HCl.
Which of the following statements is true? **(1 mark)**

A. Au is a weaker reducing agent than H_2
B. Au is a stronger reducing agent than H_2
C. Au is a weaker oxidizing agent than H^+
D. Au is a stronger oxidizing agent than H^+

42. Which two species will react spontaneously with each other at standard conditions? **(1 mark)**

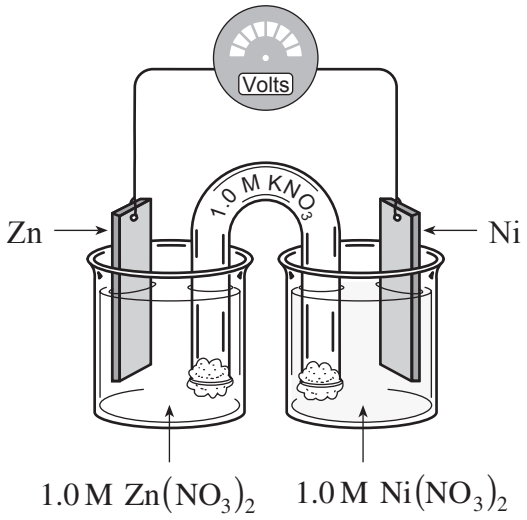
A. Cl_2 and Br^-
B. Zn and Al^{3+}
C. Au and Sn^{2+}
D. I_2 and $SO_4{}^{2-}$

43. What occurs when a piece of Zn is placed in 1.0 M $Cu(NO_3)_2$? **(1 mark)**

A. $[Cu^{2+}]$ decreases
B. $[Zn^{2+}]$ decreases
C. $[NO_3{}^-]$ increases
D. no change occurs

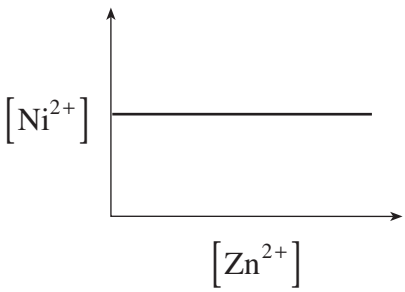
OVER

Use the following diagram to answer questions 44 to 46.

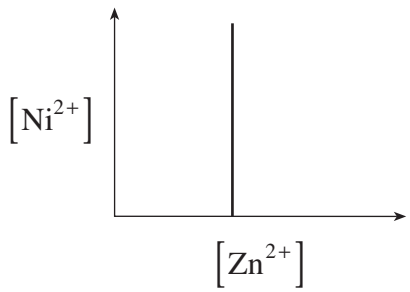


44. Which of the following diagrams represents the relationship between $\left[Zn^{2+}\right]$ and $\left[Ni^{2+}\right]$ as the cell is in operation? **(1 mark)**

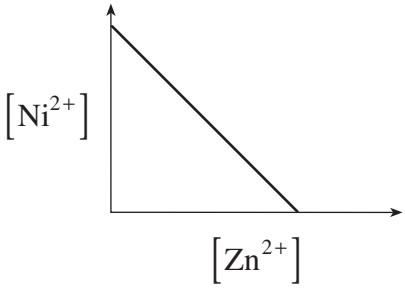
A.



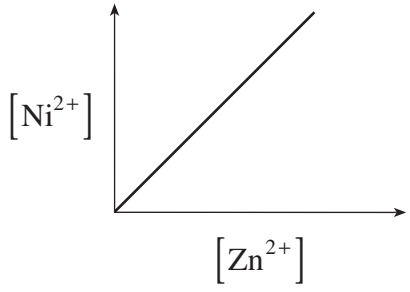
B.



C.



D.



45. The $E°$ for the cell in the diagram is **(1 mark)**

A. -1.02 Volts
B. -0.50 Volts
C. $+0.50$ Volts
D. $+1.02$ Volts

46. Which of the following does not affect the cell potential? **(1 mark)**

A. $\left[Ni^{2+}\right]$
B. $\left[Zn^{2+}\right]$
C. temperature
D. surface area of the electrodes

---

47. What type of ions move toward each electrode in an electrolytic cell? **(2 marks)**

	Anode	Cathode
A.	anions	cations
B.	cations	anions
C.	anions	anions
D.	cations	cations

48. The electrolysis of 1.0 M NaI using inert electrodes will produce **(2 marks)**

A. sodium and iodine.
B. sodium and oxygen.
C. hydrogen and iodine.
D. hydrogen and oxygen.

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

OVER

THIS PAGE INTENTIONALLY BLANK

PART B: WRITTEN RESPONSE

Value: 40 marks **Suggested Time: 50 minutes**

INSTRUCTIONS:	You will be expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner. Your steps and assumptions leading to a solution must be written in the spaces below the questions. Answers must include units where appropriate and be given to the correct number of significant figures. **For questions involving calculation, full marks will NOT be given for providing only an answer.**

1. Consider the following proposed reaction mechanism:

Step 1	$Fe^{3+} + H_2O_2 \rightarrow FeH_2O_2^{3+}$
Step 2	$FeH_2O_2^{3+} \rightarrow FeOH^{3+} + HO$
Step 3	$HO + H_2O_2 \rightarrow H_2O + HO_2$
Step 4	$FeOH^{3+} + HO_2 \rightarrow Fe^{3+} + H_2O + O_2$

a) Write the overall reaction. **(2 marks)**

b) Define the term *catalyst* and identify a catalyst in the above mechanism. **(2 marks)**

Definition: _____

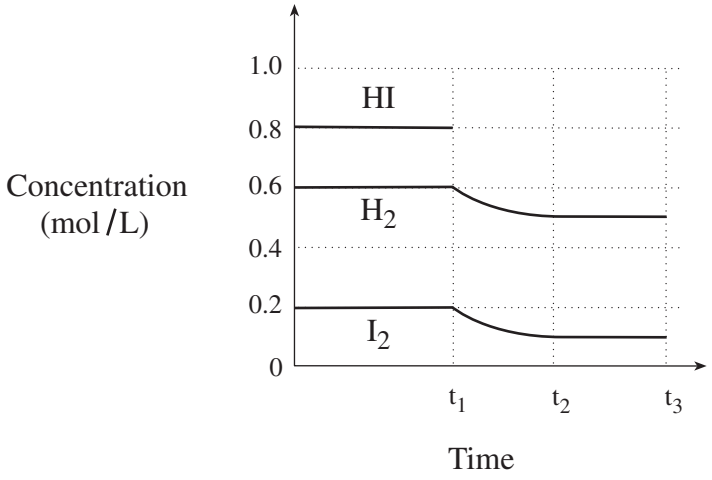
_____

Catalyst: _____

OVER

2. Consider the following graph for the reaction:

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



The temperature is increased at t_1 and equilibrium is re-established at t_2.

a) On the above graph, sketch the line representing the $[HI]$ between time t_1 and t_3. **(1 mark)**

b) Calculate the value of K_{eq} after t_2. **(2 marks)**

3. Consider the following equilibrium system:

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

A $1.00\,L$ container is initially filled with $0.100\,mol$ SO_2 and $0.100\,mol$ O_2.
At equilibrium the O_2 concentration is $0.060\,mol/L$. Calculate the value of K_{eq}. **(4 marks)**

OVER

4. Hard water, containing Ca^{2+} ions, forms a precipitate with sodium stearate $\left(NaC_{18}H_{35}O_2\right)$.

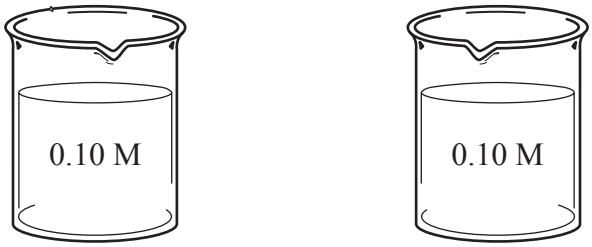
   a) Write the net ionic reaction that represents this precipitation. **(2 marks)**

   b) Identify another compound that could be used to remove Ca^{2+} from hard water. **(1 mark)**

5. Calculate the mass of $SrCO_3$ dissolved in $1.00\,L$ of a saturated solution of $SrCO_3$. **(3 marks)**

6. Consider the 0.10 M solutions of the following two acids:

Acid HA **Acid HB**



pH = 1.00 pH = 2.87

a) What can you conclude about the acids that will explain these different pH values? **(1 mark)**

You can conclude that acid HA: _____

You can conclude that acid HB: _____

b) Compare the volume of 0.10 M NaOH needed to neutralize equal volumes of each of these acid samples. **(1 mark)**

_____

_____

OVER

7. Consider a $1.0\,M$ solution of NH_4F.

a) Write both hydrolysis reactions that occur when NH_4F is dissolved in water. **(2 marks)**

b) Will the above NH_4F solution be acidic, basic, or neutral?
Support your answer with calculations. **(2 marks)**

8. An indicator is often used during acid-base titrations.

a) Define the term *transition point* for an indicator. **(1 mark)**

_____

_____

b) Calculate the K_a value for methyl red. **(1 mark)**

c) A mixture of indicators is made by combining equal amounts of methyl orange and bromthymol blue. Complete the following table, showing the colour of each indicator and the mixture at pH of 5 and pH of 9. **(2 marks)**

	Colour of methyl orange	Colour of bromthymol blue	Colour of mixture
pH=5			
pH=9			

9. Will $HC_2O_4^-$ act predominantly as an acid or as a base in solution? Support your answer with calculations. **(3 marks)**

OVER

10. Consider the following redox reaction in acidic solution:

$$MnO_4^- + H_2O_2 \rightarrow Mn^{2+} + O_2 \qquad \text{(acidic)}$$

a) Write a balanced equation for the above reaction. **(4 marks)**

b) The above reaction was used for a redox titration. At the equivalence point 5.684×10^{-4} mol $KMnO_4$ was required to titrate 5.00 mL of H_2O_2 solution. Calculate the $[H_2O_2]$. **(2 marks)**

11. Cathodic protection is one method used to inhibit the corrosion of iron.

a) Explain the principle of *cathodic protection*. **(2 marks)**

b) Identify **two** methods, other than cathodic protection, that could be used to inhibit the corrosion of iron. **(2 marks)**

i)

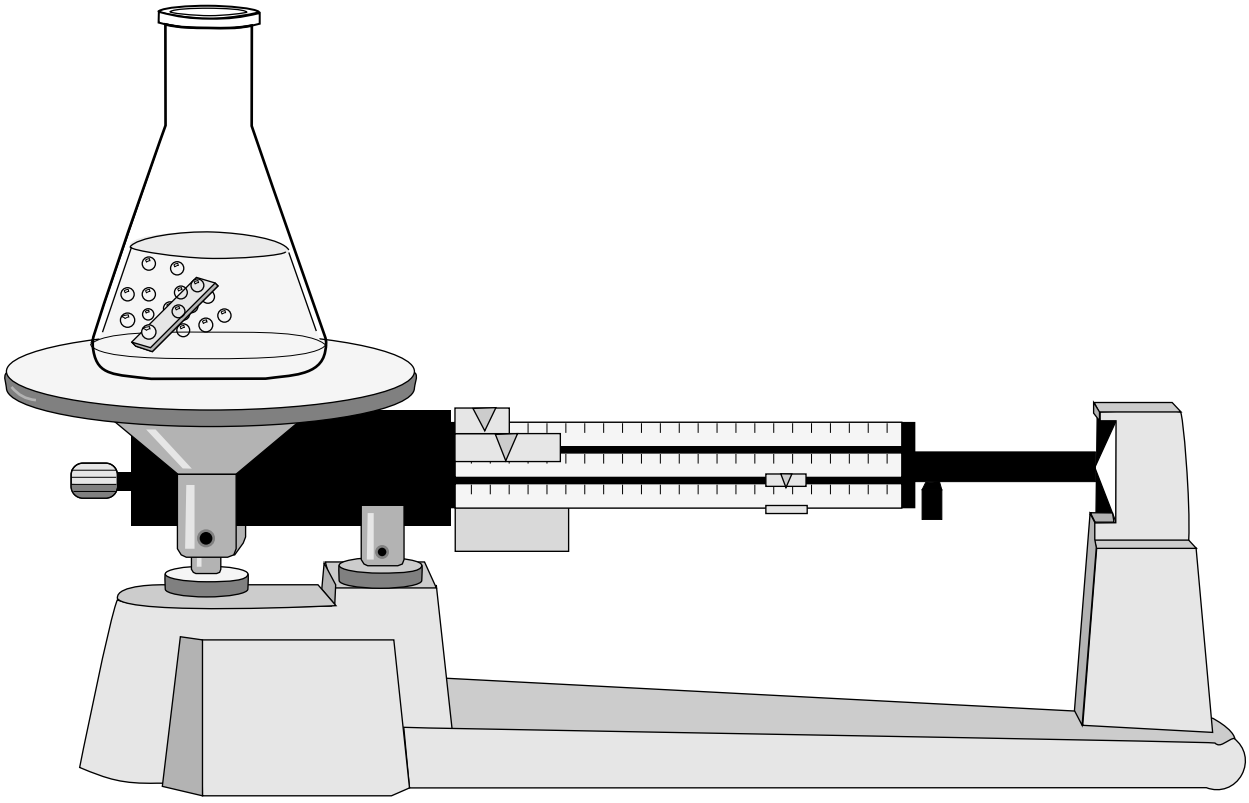
ii)

END OF EXAMINATION

Data Booklet

CHEMISTRY 12

Work done in this booklet
will not be marked.



Revised January 2000

CONTENTS

REFERENCE

D.R. Lide, *CRC Handbook of Chemistry and Physics*, 80th edition, CRC Press, Boca Raton, 1999.

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 **H** Hydrogen 1.0																	2 **He** Helium 4.0
3 **Li** Lithium 6.9	4 **Be** Beryllium 9.0											5 **B** Boron 10.8	6 **C** Carbon 12.0	7 **N** Nitrogen 14.0	8 **O** Oxygen 16.0	9 **F** Fluorine 19.0	10 **Ne** Neon 20.2
11 **Na** Sodium 23.0	12 **Mg** Magnesium 24.3											13 **Al** Aluminum 27.0	14 **Si** Silicon 28.1	15 **P** Phosphorus 31.0	16 **S** Sulphur 32.1	17 **Cl** Chlorine 35.5	18 **Ar** Argon 39.9
19 **K** Potassium 39.1	20 **Ca** Calcium 40.1	21 **Sc** Scandium 45.0	22 **Ti** Titanium 47.9	23 **V** Vanadium 50.9	24 **Cr** Chromium 52.0	25 **Mn** Manganese 54.9	26 **Fe** Iron 55.8	27 **Co** Cobalt 58.9	28 **Ni** Nickel 58.7	29 **Cu** Copper 63.5	30 **Zn** Zinc 65.4	31 **Ga** Gallium 69.7	32 **Ge** Germanium 72.6	33 **As** Arsenic 74.9	34 **Se** Selenium 79.0	35 **Br** Bromine 79.9	36 **Kr** Krypton 83.8
37 **Rb** Rubidium 85.5	38 **Sr** Strontium 87.6	39 **Y** Yttrium 88.9	40 **Zr** Zirconium 91.2	41 **Nb** Niobium 92.9	42 **Mo** Molybdenum 95.9	43 **Tc** Technetium (98)	44 **Ru** Ruthenium 101.1	45 **Rh** Rhodium 102.9	46 **Pd** Palladium 106.4	47 **Ag** Silver 107.9	48 **Cd** Cadmium 112.4	49 **In** Indium 114.8	50 **Sn** Tin 118.7	51 **Sb** Antimony 121.8	52 **Te** Tellurium 127.6	53 **I** Iodine 126.9	54 **Xe** Xenon 131.3
55 **Cs** Cesium 132.9	56 **Ba** Barium 137.3	57 **La** Lanthanum 138.9	72 **Hf** Hafnium 178.5	73 **Ta** Tantalum 180.9	74 **W** Tungsten 183.8	75 **Re** Rhenium 186.2	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.2	78 **Pt** Platinum 195.1	79 **Au** Gold 197.0	80 **Hg** Mercury 200.6	81 **Tl** Thallium 204.4	82 **Pb** Lead 207.2	83 **Bi** Bismuth 209.0	84 **Po** Polonium (209)	85 **At** Astatine (210)	86 **Rn** Radon (222)
87 **Fr** Francium (223)	88 **Ra** Radium (226)	89 **Ac** Actinium (227)	104 **Rf** Rutherfordium (261)	105 **Db** Dubnium (262)	106 **Sg** Seaborgium (263)	107 **Bh** Bohrium (262)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)									

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

58	59	60	61	62	63	64	65	66	67	68	69	70	71
Ce Cerium 140.1	**Pr** Praseodymium 140.9	**Nd** Neodymium 144.2	**Pm** Promethium (145)	**Sm** Samarium 150.4	**Eu** Europium 152.0	**Gd** Gadolinium 157.3	**Tb** Terbium 158.9	**Dy** Dysprosium 162.5	**Ho** Holmium 164.9	**Er** Erbium 167.3	**Tm** Thulium 168.9	**Yb** Ytterbium 173.0	**Lu** Lutetium 175.0
90 **Th** Thorium 232.0	91 **Pa** Protactinium 231.0	92 **U** Uranium 238.0	93 **Np** Neptunium (237)	94 **Pu** Plutonium (244)	95 **Am** Americium (243)	96 **Cm** Curium (247)	97 **Bk** Berkelium (247)	98 **Cf** Californium (251)	99 **Es** Einsteinium (252)	100 **Fm** Fermium (257)	101 **Md** Mendelevium (258)	102 **No** Nobelium (259)	103 **Lr** Lawrencium (262)

Based on mass of C^{12} at 12.00.

Values in parentheses are the masses of the most stable or best known isotopes for elements which do not occur naturally.

ATOMIC MASSES OF THE ELEMENTS

Based on mass of C^{12} at 12.00.
Values in parentheses are the mass number of the most stable or best known isotopes for elements that do not occur naturally.

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

NAMES, FORMULAE, AND CHARGES OF SOME COMMON IONS

* *Aqueous solutions are readily oxidized by air.*
** *Not stable in aqueous solutions.*

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

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

SOLUBILITY OF COMMON COMPOUNDS IN WATER

The term soluble here means > 0.1 mol/L at 25°C.

Negative Ions (Anions)	Positive Ions (Cations)	Solubility of Compounds
All	Alkali ions: Li^+, Na^+, K^+, Rb^+, Cs^+, Fr^+	Soluble
All	Hydrogen ion: H^+	Soluble
All	Ammonium ion: NH_4^+	Soluble
Nitrate, NO_3^-	All	Soluble
Chloride, Cl^- or Bromide, Br^- or Iodide, I^-	All others	Soluble
	Ag^+, Pb^{2+}, Cu^+	Low Solubility
Sulphate, SO_4^{2-}	All others	Soluble
	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}	Low Solubility
Sulphide, S^{2-}	Alkali ions, H^+, NH_4^+, Be^{2+}, Mg^{2+}, Ca^{2+}, Sr^{2+}, Ba^{2+}	Soluble
	All others	Low Solubility
Hydroxide, OH^-	Alkali ions, H^+, NH_4^+, Sr^{2+}	Soluble
	All others	Low Solubility
Phosphate, PO_4^{3-} or Carbonate, CO_3^{2-} or Sulphite, SO_3^{2-}	Alkali ions, H^+, NH_4^+	Soluble
	All others	Low Solubility

SOLUBILITY PRODUCT CONSTANTS AT 25°C

Name	Formula	K_{sp}
Barium carbonate	$BaCO_3$	2.6×10^{-9}
Barium chromate	$BaCrO_4$	1.2×10^{-10}
Barium sulphate	$BaSO_4$	1.1×10^{-10}
Calcium carbonate	$CaCO_3$	5.0×10^{-9}
Calcium oxalate	CaC_2O_4	2.3×10^{-9}
Calcium sulphate	$CaSO_4$	7.1×10^{-5}
Copper(I) iodide	CuI	1.3×10^{-12}
Copper(II) iodate	$Cu(IO_3)_2$	6.9×10^{-8}
Copper(II) sulphide	CuS	6.0×10^{-37}
Iron(II) hydroxide	$Fe(OH)_2$	4.9×10^{-17}
Iron(II) sulphide	FeS	6.0×10^{-19}
Iron(III) hydroxide	$Fe(OH)_3$	2.6×10^{-39}
Lead(II) bromide	$PbBr_2$	6.6×10^{-6}
Lead(II) chloride	$PbCl_2$	1.2×10^{-5}
Lead(II) iodate	$Pb(IO_3)_2$	3.7×10^{-13}
Lead(II) iodide	PbI_2	8.5×10^{-9}
Lead(II) sulphate	$PbSO_4$	1.8×10^{-8}
Magnesium carbonate	$MgCO_3$	6.8×10^{-6}
Magnesium hydroxide	$Mg(OH)_2$	5.6×10^{-12}
Silver bromate	$AgBrO_3$	5.3×10^{-5}
Silver bromide	$AgBr$	5.4×10^{-13}
Silver carbonate	Ag_2CO_3	8.5×10^{-12}
Silver chloride	$AgCl$	1.8×10^{-10}
Silver chromate	Ag_2CrO_4	1.1×10^{-12}
Silver iodate	$AgIO_3$	3.2×10^{-8}
Silver iodide	AgI	8.5×10^{-17}
Strontium carbonate	$SrCO_3$	5.6×10^{-10}
Strontium fluoride	SrF_2	4.3×10^{-9}
Strontium sulphate	$SrSO_4$	3.4×10^{-7}
Zinc sulphide	ZnS	2.0×10^{-25}

RELATIVE STRENGTHS OF BRØNSTED-LOWRY ACIDS AND BASES

in aqueous solution at room temperature.

STRENGTH OF ACID: STRONG (top) → WEAK (bottom)

STRENGTH OF BASE: WEAK (top) → STRONG (bottom)

Name of Acid	Acid		Base	K_a
Perchloric	$HClO_4$	$\rightarrow$	$H^+ + ClO_4^-$	very large
Hydriodic	HI	$\rightarrow$	$H^+ + I^-$	very large
Hydrobromic	HBr	$\rightarrow$	$H^+ + Br^-$	very large
Hydrochloric	HCl	$\rightarrow$	$H^+ + Cl^-$	very large
Nitric	HNO_3	$\rightarrow$	$H^+ + NO_3^-$	very large
Sulphuric	H_2SO_4	$\rightarrow$	$H^+ + HSO_4^-$	very large
Hydronium Ion	H_3O^+	$\rightleftarrows$	$H^+ + H_2O$	1.0
Iodic	HIO_3	$\rightleftarrows$	$H^+ + IO_3^-$	1.7×10^{-1}
Oxalic	$H_2C_2O_4$	$\rightleftarrows$	$H^+ + HC_2O_4^-$	5.9×10^{-2}
Sulphurous $(SO_2 + H_2O)$	H_2SO_3	$\rightleftarrows$	$H^+ + HSO_3^-$	1.5×10^{-2}
Hydrogen sulphate ion	HSO_4^-	$\rightleftarrows$	$H^+ + SO_4^{2-}$	1.2×10^{-2}
Phosphoric	H_3PO_4	$\rightleftarrows$	$H^+ + H_2PO_4^-$	7.5×10^{-3}
Hexaaquoiron ion, iron(III) ion	$Fe(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Fe(H_2O)_5(OH)^{2+}$	6.0×10^{-3}
Citric	$H_3C_6H_5O_7$	$\rightleftarrows$	$H^+ + H_2C_6H_5O_7^-$	7.1×10^{-4}
Nitrous	HNO_2	$\rightleftarrows$	$H^+ + NO_2^-$	4.6×10^{-4}
Hydrofluoric	HF	$\rightleftarrows$	$H^+ + F^-$	3.5×10^{-4}
Methanoic, formic	$HCOOH$	$\rightleftarrows$	$H^+ + HCOO^-$	1.8×10^{-4}
Hexaaquochromium ion, chromium(III) ion	$Cr(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Cr(H_2O)_5(OH)^{2+}$	1.5×10^{-4}
Benzoic	C_6H_5COOH	$\rightleftarrows$	$H^+ + C_6H_5COO^-$	6.5×10^{-5}
Hydrogen oxalate ion	$HC_2O_4^-$	$\rightleftarrows$	$H^+ + C_2O_4^{2-}$	6.4×10^{-5}
Ethanoic, acetic	CH_3COOH	$\rightleftarrows$	$H^+ + CH_3COO^-$	1.8×10^{-5}
Dihydrogen citrate ion	$H_2C_6H_5O_7^-$	$\rightleftarrows$	$H^+ + HC_6H_5O_7^{2-}$	1.7×10^{-5}
Hexaaquoaluminum ion, aluminum ion	$Al(H_2O)_6^{3+}$	$\rightleftarrows$	$H^+ + Al(H_2O)_5(OH)^{2+}$	1.4×10^{-5}
Carbonic $(CO_2 + H_2O)$	H_2CO_3	$\rightleftarrows$	$H^+ + HCO_3^-$	4.3×10^{-7}
Monohydrogen citrate ion	$HC_6H_5O_7^{2-}$	$\rightleftarrows$	$H^+ + C_6H_5O_7^{3-}$	4.1×10^{-7}
Hydrogen sulphite ion	HSO_3^-	$\rightleftarrows$	$H^+ + SO_3^{2-}$	1.0×10^{-7}
Hydrogen sulphide	H_2S	$\rightleftarrows$	$H^+ + HS^-$	9.1×10^{-8}
Dihydrogen phosphate ion	$H_2PO_4^-$	$\rightleftarrows$	$H^+ + HPO_4^{2-}$	6.2×10^{-8}
Boric	H_3BO_3	$\rightleftarrows$	$H^+ + H_2BO_3^-$	7.3×10^{-10}
Ammonium ion	NH_4^+	$\rightleftarrows$	$H^+ + NH_3$	5.6×10^{-10}
Hydrocyanic	HCN	$\rightleftarrows$	$H^+ + CN^-$	4.9×10^{-10}
Phenol	C_6H_5OH	$\rightleftarrows$	$H^+ + C_6H_5O^-$	1.3×10^{-10}
Hydrogen carbonate ion	HCO_3^-	$\rightleftarrows$	$H^+ + CO_3^{2-}$	5.6×10^{-11}
Hydrogen peroxide	H_2O_2	$\rightleftarrows$	$H^+ + HO_2^-$	2.4×10^{-12}
Monohydrogen phosphate ion	HPO_4^{2-}	$\rightleftarrows$	$H^+ + PO_4^{3-}$	2.2×10^{-13}
Water	H_2O	$\rightleftarrows$	$H^+ + OH^-$	1.0×10^{-14}
Hydroxide ion	OH^-	$\leftarrow$	$H^+ + O^{2-}$	very small
Ammonia	NH_3	$\leftarrow$	$H^+ + NH_2^-$	very small

ACID-BASE INDICATORS

Indicator	pH Range in Which Colour Change Occurs	Colour Change as pH Increases
Methyl violet	0.0 – 1.6	yellow to blue
Thymol blue	1.2 – 2.8	red to yellow
Orange IV	1.4 – 2.8	red to yellow
Methyl orange	3.2 – 4.4	red to yellow
Bromcresol green	3.8 – 5.4	yellow to blue
Methyl red	4.8 – 6.0	red to yellow
Chlorophenol red	5.2 – 6.8	yellow to red
Bromthymol blue	6.0 – 7.6	yellow to blue
Phenol red	6.6 – 8.0	yellow to red
Neutral red	6.8 – 8.0	red to amber
Thymol blue	8.0 – 9.6	yellow to blue
Phenolphthalein	8.2 – 10.0	colourless to pink
Thymolphthalein	9.4 – 10.6	colourless to blue
Alizarin yellow	10.1 – 12.0	yellow to red
Indigo carmine	11.4 – 13.0	blue to yellow

STANDARD REDUCTION POTENTIALS OF HALF-CELLS

Ionic concentrations are at 1M in water at 25° C.

Oxidizing Agents		Reducing Agents	E° (Volts)
$F_{2(g)} + 2e^-$	⇄	$2F^-$	+2.87
$S_2O_8^{2-} + 2e^-$	⇄	$2SO_4^{2-}$	+2.01
$H_2O_2 + 2H^+ + 2e^-$	⇄	$2H_2O$	+1.78
$MnO_4^- + 8H^+ + 5e^-$	⇄	$Mn^{2+} + 4H_2O$	+1.51
$Au^{3+} + 3e^-$	⇄	$Au_{(s)}$	+1.50
$BrO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}Br_{2(\ell)} + 3H_2O$	+1.48
$ClO_4^- + 8H^+ + 8e^-$	⇄	$Cl^- + 4H_2O$	+1.39
$Cl_{2(g)} + 2e^-$	⇄	$2Cl^-$	+1.36
$Cr_2O_7^{2-} + 14H^+ + 6e^-$	⇄	$2Cr^{3+} + 7H_2O$	+1.23
$\frac{1}{2}O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O	+1.23
$MnO_{2(s)} + 4H^+ + 2e^-$	⇄	$Mn^{2+} + 2H_2O$	+1.22
$IO_3^- + 6H^+ + 5e^-$	⇄	$\frac{1}{2}I_{2(s)} + 3H_2O$	+1.20
$Br_{2(\ell)} + 2e^-$	⇄	$2Br^-$	+1.09
$AuCl_4^- + 3e^-$	⇄	$Au_{(s)} + 4Cl^-$	+1.00
$NO_3^- + 4H^+ + 3e^-$	⇄	$NO_{(g)} + 2H_2O$	+0.96
$Hg^{2+} + 2e^-$	⇄	$Hg_{(\ell)}$	+0.85
$\frac{1}{2}O_{2(g)} + 2H^+(10^{-7}\,M) + 2e^-$	⇄	H_2O	+0.82
$2NO_3^- + 4H^+ + 2e^-$	⇄	$N_2O_4 + 2H_2O$	+0.80
$Ag^+ + e^-$	⇄	$Ag_{(s)}$	+0.80
$\frac{1}{2}Hg_2^{2+} + e^-$	⇄	$Hg_{(\ell)}$	+0.80
$Fe^{3+} + e^-$	⇄	Fe^{2+}	+0.77
$O_{2(g)} + 2H^+ + 2e^-$	⇄	H_2O_2	+0.70
$MnO_4^- + 2H_2O + 3e^-$	⇄	$MnO_{2(s)} + 4OH^-$	+0.60
$I_{2(s)} + 2e^-$	⇄	$2I^-$	+0.54
$Cu^+ + e^-$	⇄	$Cu_{(s)}$	+0.52
$H_2SO_3 + 4H^+ + 4e^-$	⇄	$S_{(s)} + 3H_2O$	+0.45
$Cu^{2+} + 2e^-$	⇄	$Cu_{(s)}$	+0.34
$SO_4^{2-} + 4H^+ + 2e^-$	⇄	$H_2SO_3 + H_2O$	+0.17
$Cu^{2+} + e^-$	⇄	Cu^+	+0.15
$Sn^{4+} + 2e^-$	⇄	Sn^{2+}	+0.15
$S_{(s)} + 2H^+ + 2e^-$	⇄	$H_2S_{(g)}$	+0.14
$2H^+ + 2e^-$	⇄	$H_{2(g)}$	+0.00
$Pb^{2+} + 2e^-$	⇄	$Pb_{(s)}$	−0.13
$Sn^{2+} + 2e^-$	⇄	$Sn_{(s)}$	−0.14
$Ni^{2+} + 2e^-$	⇄	$Ni_{(s)}$	−0.26
$H_3PO_4 + 2H^+ + 2e^-$	⇄	$H_3PO_3 + H_2O$	−0.28
$Co^{2+} + 2e^-$	⇄	$Co_{(s)}$	−0.28
$Se_{(s)} + 2H^+ + 2e^-$	⇄	H_2Se	−0.40
$Cr^{3+} + e^-$	⇄	Cr^{2+}	−0.41
$2H_2O + 2e^-$	⇄	$H_2 + 2OH^-(10^{-7}\,M)$	−0.41
$Fe^{2+} + 2e^-$	⇄	$Fe_{(s)}$	−0.45
$Ag_2S_{(s)} + 2e^-$	⇄	$2Ag_{(s)} + S^{2-}$	−0.69
$Cr^{3+} + 3e^-$	⇄	$Cr_{(s)}$	−0.74
$Zn^{2+} + 2e^-$	⇄	$Zn_{(s)}$	−0.76
$Te_{(s)} + 2H^+ + 2e^-$	⇄	H_2Te	−0.79
$2H_2O + 2e^-$	⇄	$H_{2(g)} + 2OH^-$	−0.83
$Mn^{2+} + 2e^-$	⇄	$Mn_{(s)}$	−1.19
$Al^{3+} + 3e^-$	⇄	$Al_{(s)}$	−1.66
$Mg^{2+} + 2e^-$	⇄	$Mg_{(s)}$	−2.37
$Na^+ + e^-$	⇄	$Na_{(s)}$	−2.71
$Ca^{2+} + 2e^-$	⇄	$Ca_{(s)}$	−2.87
$Sr^{2+} + 2e^-$	⇄	$Sr_{(s)}$	−2.89
$Ba^{2+} + 2e^-$	⇄	$Ba_{(s)}$	−2.91
$K^+ + e^-$	⇄	$K_{(s)}$	−2.93
$Rb^+ + e^-$	⇄	$Rb_{(s)}$	−2.98
$Cs^+ + e^-$	⇄	$Cs_{(s)}$	−3.03
$Li^+ + e^-$	⇄	$Li_{(s)}$	−3.04

Overpotential Effect

Overpotential Effect

STRONG ↑ STRENGTH OF OXIDIZING AGENT ↓ WEAK

WEAK ↑ STRENGTH OF REDUCING AGENT ↓ STRONG