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BRITISH COLUMBIA

Chemistry 12

APRIL 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. ☐ . ☐

(5)

Question 6:

6. ☐ . ☐

(2)

Question 2:

2. ☐ . ☐

(3)

Question 7:

7. ☐ . ☐

(5)

Question 3:

3. ☐ . ☐

(4)

Question 8:

8. ☐ . ☐

(5)

Question 4:

4. ☐ . ☐

(3)

Question 9:

9. ☐ . ☐

(5)

Question 5:

5. ☐ . ☐

(4)

Question 10:

10. ☐ . ☐

(4)

CHEMISTRY 12

APRIL 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: 10 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.

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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. Which of the following reactions occurs most rapidly at standard conditions? **(1 mark)**

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

   B. $CaO_{(s)} + 3C_{(s)} \rightarrow CaC_{2(s)} + CO_{(g)}$

   C. $SnO_{2(s)} + 2CO_{(g)} \rightarrow Sn_{(s)} + 2CO_{2(g)}$

   D. $2AgNO_{3(aq)} + Na_2CrO_{4(aq)} \rightarrow Ag_2CrO_{4(s)} + 2NaNO_{3(aq)}$

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

$$CaO_{(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(\ell)}$$

   Which of the following could be used to measure the rate of this reaction?

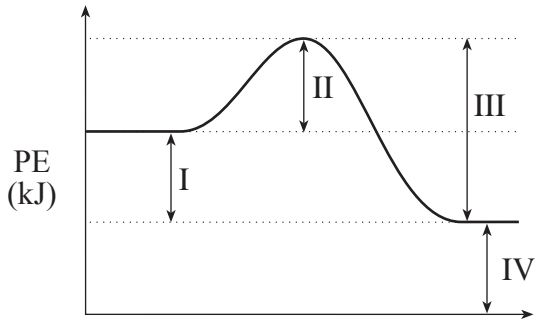
   A. change in acidity
   B. change in volume
   C. change in pressure
   D. change in total mass

3. In order for a collision between reactant particles to be successful **(1 mark)**

   A. a ΔH must be positive.
   B. the system must be closed.
   C. there must be sufficient KE.
   D. the change in KE must be less than the change in PE.

OVER

4. Consider the following PE diagram: **(1 mark)**



The activation energy for the forward reaction is represented by

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

5. What is the relationship between the activation energy and the rate of a reaction? **(1 mark)**

A. When the activation energy is high, the rate of reaction is fast.
B. When the activation energy is low, the rate of reaction is slow.
C. When the activation energy is high, the rate of reaction is slow.
D. There is no relationship between activation energy and rate of reaction.

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

Step 1	$OCl^- + H_2O \rightarrow HOCl + OH^-$
Step 2	$I^- + HOCl \rightarrow HOI + Cl^-$
Step 3	$HOI + OH^- \rightarrow H_2O + OI^-$

Which of the following is correct for the overall reaction?

A. HOI is a product.
B. H_2O is a reactant.
C. HOCl is a catalyst.
D. OH^- is a reaction intermediate.

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

$$2ICl_{(g)} \rightleftarrows I_{2(g)} + Cl_{2(g)}$$

Some ICl is added to an empty flask. How do the reaction rates change as the system approaches equilibrium?

	forward rate	reverse rate
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

8. In an equilibrium system, continuing microscopic changes indicate that the equilibrium is **(1 mark)**

A. dynamic.
B. complete.
C. exothermic.
D. spontaneous.

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

$$4CuO_{(s)} + \text{energy} \rightleftarrows 2Cu_2O_{(s)} + O_{2(g)}$$

The equilibrium will shift to the right as a result of

A. adding $CuO_{(s)}$.

B. removing $O_{2(g)}$.

C. adding a catalyst.

D. decreasing the temperature.

OVER

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

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

The volume of the system is decreased. The equilibrium shifts

A. left since the reverse rate is greater than the forward rate.
B. left since the forward rate is greater than the reverse rate.
C. right since the reverse rate is greater than the forward rate.
D. right since the forward rate is greater than the reverse rate.

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

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

When the temperature is increased, the equilibrium will shift

A. left with K_{eq} becoming larger.
B. right with K_{eq} becoming larger.
C. left with K_{eq} becoming smaller.
D. right with K_{eq} becoming smaller.

12. Starting with equal concentrations of reactants, which of the following will be closest to completion at equilibrium? **(1 mark)**

A. $CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)}$ $\qquad K_{eq} = 22$
B. $PCl_{3(g)} + Cl_{2(g)} \rightleftarrows PCl_{5(g)}$ $\qquad K_{eq} = 2.9 \times 10^{-2}$
C. $CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)}$ $\qquad K_{eq} = 4.5 \times 10^{-9}$
D. $CH_3O_{2(g)} + NO_{2(g)} \rightleftarrows CH_3O_2NO_{2(g)}$ $\qquad K_{eq} = 2.1 \times 10^{-12}$

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

$$2COF_{2(g)} \rightleftarrows CO_{2(g)} + CF_{4(g)}$$

At equilibrium, a 1.00 L container contains 7.07×10^{-4} mol COF_2, 1.00×10^{-3} mol CO_2, and 1.00×10^{-3} mol CF_4. What is the value of K_{eq}?

A. 7.07×10^{-4}
B. 1.41×10^{-3}
C. 0.500
D. 2.00

14. Which of the following dissolves in water to form a molecular solution? **(1 mark)**

A. KCl
B. Na_2O
C. NH_4Br
D. C_2H_5OH

15. A saturated solution is formed by adding 10.0 g $PbI_{2(s)}$ to 10.0 mL of water in a beaker. Describe the situation which exists in the beaker. **(1 mark)**

A. $\left[Pb^{2+}\right] = \left[I^{-}\right]$
B. moles $PbI_{2(s)}$ = moles $Pb^{2+}_{(aq)}$
C. mass of $PbI_{2(s)}$ = mass of $PbI_{2(aq)}$
D. rate of crystalization = rate of dissociation

16. What is the concentration of barium ions in a 1.00 L solution containing 2.08 g of $BaCl_2$? **(1 mark)**

A. 1.00×10^{-2} M
B. 1.21×10^{-2} M
C. 2.00×10^{-2} M
D. 2.08 M

OVER

17. Which of the following salts has low solubility? **(1 mark)**

A. MgS
B. $ZnCl_2$
C. $SrSO_4$
D. $AgNO_3$

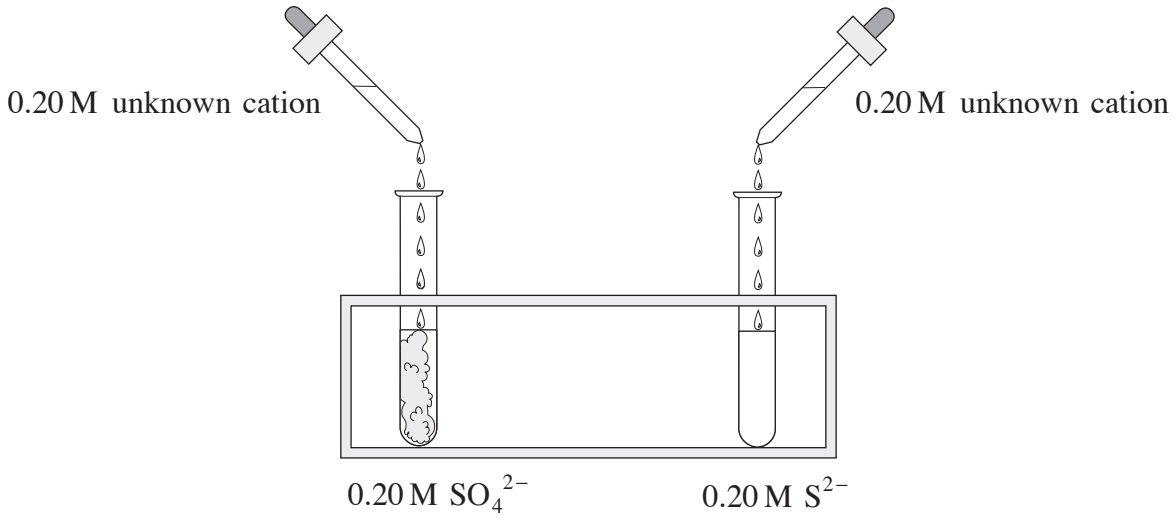
18. Consider the following solubility equilibrium: **(2 marks)**

$$AgCl_{(s)} \rightleftarrows Ag^+_{(aq)} + Cl^-_{(aq)}$$

Some $NaCl_{(s)}$ is added to the equilibrium. When equilibrium is reestablished, how have the ion concentrations changed from the original equilibrium?

	$[Ag^+]$	$[Cl^-]$
A.	decreased	increased
B.	decreased	decreased
C.	increased	decreased
D.	increased	increased

19. A precipitate forms when a $0.20\,M$ solution containing an unknown cation is added to SO_4^{2-}, but not when an equal volume is added to S^{2-}. **(2 marks)**



The unknown cation is

A. Na^+
B. Ca^{2+}
C. Pb^{2+}
D. Zn^{2+}

20. The K_{sp} expression for a saturated solution of $Ni_3(PO_4)_2$ is **(1 mark)**

A. $K_{sp} = \left[Ni^{2+}\right]^3 \left[PO_4^{3-}\right]^2$
B. $K_{sp} = \left[Ni^{2+}\right]^2 \left[PO_4^{3-}\right]^3$
C. $K_{sp} = \left[3Ni^{2+}\right]\left[2PO_4^{3-}\right]$
D. $K_{sp} = \left[3Ni^{2+}\right]^3 \left[2PO_4^{3-}\right]^2$

21. Which of the following are general properties of bases in aqueous solution? **(2 marks)**

A. feel slippery and increase $\left[H_3O^+\right]$
B. turn litmus red and accept a proton
C. conduct electricity and turn litmus blue
D. feel slippery and react with Au to produce $H_{2(g)}$

OVER

22. The conjugate base of $H_2PO_4^-$ is **(1 mark)**

A. PO_4^{3-}

B. HPO_4^-

C. HPO_4^{2-}

D. H_3PO_4

23. The electrical conductivities of 0.10 M solutions of NaCl, HCN and HNO_2 are measured. The order by conductivity from highest to lowest is **(2 marks)**

A. NaCl > HNO_2 > HCN
B. HCN > HNO_2 > NaCl
C. NaCl > HCN > HNO_2
D. HNO_2 > HCN > NaCl

24. Which of the following acids has the weakest conjugate base? **(1 mark)**

A. HIO_3
B. HNO_2
C. H_3PO_4
D. CH_3COOH

25. When 10.0 mL of 0.10 M HCl is added to 10.0 mL of water, the concentration of H_3O^+ in the final solution is **(1 mark)**

A. 0.010 M
B. 0.050 M
C. 0.10 M
D. 0.20 M

26. Which of the following chemical species are amphiprotic in aqueous solution? **(2 marks)**

I.	F^-
II.	NH_4^+
III.	HPO_4^{2-}

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

27. A solution is prepared by mixing 1.50×10^{-3} mol HCl with 3.00×10^{-3} mol KOH. Calculate the moles of OH^- present after mixing. **(1 mark)**

A. 0 mol
B. 1.50×10^{-3} mol
C. 3.00×10^{-3} mol
D. 4.50×10^{-3} mol

28. Calculate the pH in a 0.020 M solution of $Sr(OH)_2$. **(2 marks)**

A. 1.40
B. 1.70
C. 12.30
D. 12.60

29. The K_b value for HPO_4^{2-} is **(1 mark)**

A. 2.2×10^{-13}
B. 6.2×10^{-8}
C. 1.6×10^{-7}
D. 7.5×10^{-3}

OVER

30. Which of the following $1.0\,M$ salt solutions is acidic? **(1 mark)**

A. BaS
B. NH_4Cl
C. $Ca(NO_3)_2$
D. $NaCH_3COO$

31. Which of the following represents the hydrolysis reaction that occurs in a solution of $K_2C_2O_4$? **(1 mark)**

A. $K_2C_2O_4 \rightleftarrows 2K^+ + C_2O_4^{2-}$
B. $K^+ + 2H_2O \rightleftarrows KOH + H_3O^+$
C. $C_2O_4^{2-} + H_2O \rightleftarrows HC_2O_4^- + OH^-$
D. $K_2C_2O_4 + H_2O \rightleftarrows K_2CO_3 + CO_2 + H_2$

32. When the indicator thymol blue is added to a $0.10\,M$ solution of an unknown acid, the solution is red. The acid could be **(1 mark)**

A. HF
B. H_2S
C. HCN
D. HNO_3

33. The complete neutralization of 15.0 mL of KOH requires 0.025 mol H_2SO_4. The [KOH] was **(1 mark)**

A. 1.50 M
B. 1.67 M
C. 3.33 M
D. 6.67 M

34. What is the $\left[H_3O^+\right]$ at the equivalence point for the titration between HBr and KOH ? **(1 mark)**

A. 1.0×10^{-9} M
B. 1.0×10^{-7} M
C. 1.0×10^{-5} M
D. 0.0 M

35. Which of the following would form a buffer solution when equal moles are mixed together? **(1 mark)**

A. HCl and NaCl
B. HCN and NaCN
C. KNO_3 and KOH
D. Na_2SO_4 and NaOH

36. Which of the following oxides dissolves to form a solution with a pH greater than 7 ? **(1 mark)**

A. SO_2
B. CO_2
C. N_2O
D. K_2O

OVER

37. The pH of acid rain could be **(1 mark)**

A. 5.0
B. 7.0
C. 9.0
D. 11.0

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

$$Zn_{(s)} + 2H^{+}_{(aq)} \rightarrow Zn^{2+}_{(aq)} + H_{2(g)}$$

The species being oxidized is

A. H_2
B. H^+
C. Zn
D. Zn^{2+}

39. When SO_4^{2-} reacts to form $S_2O_6^{2-}$, the sulphur atoms **(2 marks)**

A. lose electrons and are reduced.
B. gain electrons and are reduced.
C. lose electrons and are oxidized.
D. gain electrons and are oxidized.

40. Which of the following is a list of metals in order from strongest to weakest reducing agents? **(1 mark)**

A. Au > Ni > Rb
B. Ni > Au > Rb
C. Ni > Rb > Au
D. Rb > Ni > Au

41. Consider the following spontaneous reaction:

$$Mg_{(s)} + 2HCl_{(aq)} \rightarrow MgCl_{2(aq)} + H_{2(g)}$$

Which of the following statements is correct? **(1 mark)**

A. Mg is a weaker reducing agent than H_2

B. Mg is a weaker reducing agent than H^+

C. Mg is a stronger reducing agent than H_2

D. Mg is a stronger reducing agent than H^+

42. Which of the following will **not** react spontaneously with H_2O at standard conditions? **(1 mark)**

A. F_2

B. Ca

C. Na

D. Sn

43. When a piece of Cu is placed in 1.0 M $AgNO_3$, **(1 mark)**

A. the $\left[Ag^+\right]$ increases.

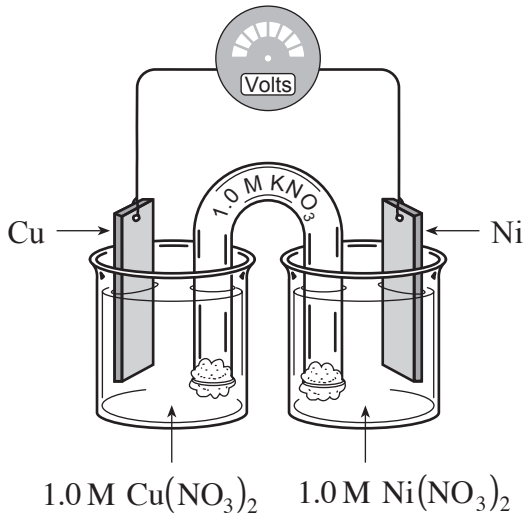
B. the $\left[Cu^{2+}\right]$ increases.

C. the $\left[NO_3^-\right]$ decreases.

D. no change occurs.

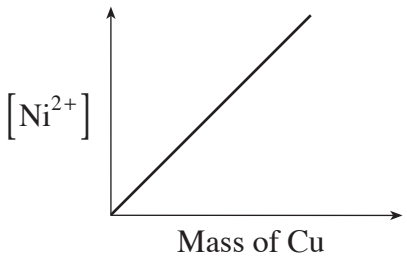
OVER

Use the following diagram to answer questions 44 and 45.

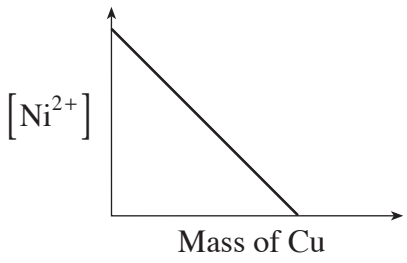


44. Which of the following diagrams represents the relationship between $[Ni^{2+}]$ and the mass of the Cu electrode as the cell above is in operation? **(1 mark)**

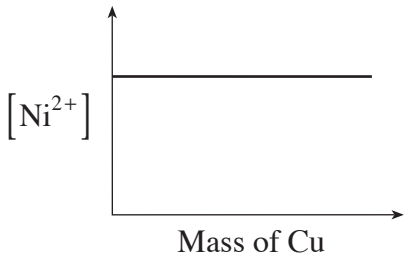
A.



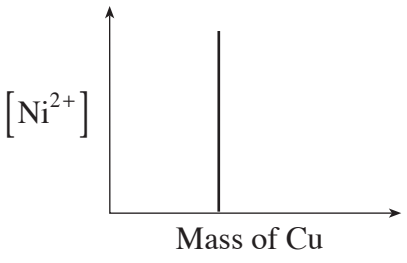
B.



C.



D.



45. The E° for the above cell is **(1 mark)**

A. –0.04 volts
B. –0.60 volts
C. +0.04 volts
D. +0.60 volts

46. Which of the following describes an electrochemical cell? **(2 marks)**

	$E°_{cell}$	Type of reaction
A.	positive	spontaneous
B.	positive	non-spontaneous
C.	negative	spontaneous
D.	negative	non-spontaneous

47. Which of the following aqueous solutions should **not** be used as an electrolyte in an electrolytic cell? **(1 mark)**

A. 1.0 M KOH
B. 1.0 M H_2SO_4
C. 1.0 M $CuSO_4$
D. 1.0 M $C_6H_{12}O_6$

48. When 1.0 M Na_2SO_4 is electrolyzed, the solution near the anode becomes **(2 marks)**

A. basic and bubbles form.
B. acidic and bubbles form.
C. basic and no bubbles form.
D. acidic and no bubbles form.

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

OVER

PART B: WRITTEN RESPONSE

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

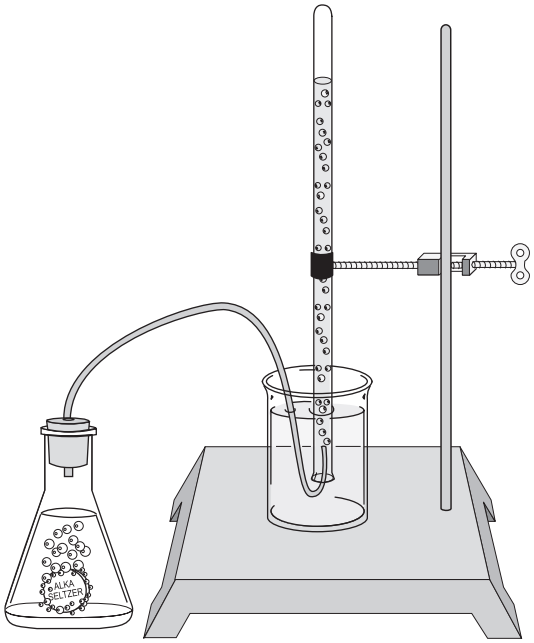
INSTRUCTIONS: You will be expected to communicate your knowledge and understanding of chemical principles in a clear and logical manner.

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. An Alka-Seltzer tablet is added to water to produce carbon dioxide gas. The gas was collected using water displacement.



The following data is recorded:

Time (s)	Volume of CO_2 (mL)
0.0	0
10.0	3.0
20.0	20.0
30.0	33.5
40.0	43.0
50.0	43.0
60.0	43.0

a) Calculate the average rate of reaction for the formation of CO_2 gas for the times:

i) $0 - 10\,s$ **(1 mark)**

ii) $10 - 20\,s$ **(1 mark)**

b) Suggest a reason why the rate of reaction from 0 to 10.0 s is slower than the rate from 10.0 to 20.0 s ? **(1 mark)**

_____

_____

c) The rate of reaction is not constant during the entire interval from 10.0 to 40.0 s. Describe the change in rate and explain a reason for the change. **(2 marks)**

_____

_____

_____

_____

OVER

2. A flask is initially filled with some HI. At equilibrium, the $[HI] = 0.80\ mol/L$. What is the $[H_2]$ at equilibrium? **(3 marks)**

$$2HI_{(g)} \rightleftarrows H_{2(g)} + I_{2(g)} \qquad K_{eq} = 0.25$$

3. Consider the following equilibrium system:

$$2NOCl_{(g)} \rightleftarrows 2NO_{(g)} + Cl_{2(g)} \qquad K_{eq} = 1.6 \times 10^{-5}$$

A 1.00 L flask is filled with 0.20 mol NOCl, 0.10 mol NO and 0.10 mol Cl_2. State and show by calculation the direction in which the reaction proceeds to reach equilibrium. **(4 marks)**

Direction: _____

Calculations:

OVER

4. In a titration, 25.00 mL of $NaCl_{(aq)}$ reacts completely with 42.20 mL of 0.100 M $AgNO_3$.
   What is the $\left[Cl^-\right]$ in the original solution? **(3 marks)**

5. The following data was obtained when $20.0\,\text{mL}$ of a saturated solution of PbI_2 was evaporated to dryness.

Mass of evaporating dish	$30.250\,\text{g}$
Mass of evaporating dish and residue	$30.262\,\text{g}$

Use this information to determine the K_{sp} of PbI_2. **(4 marks)**

OVER

6. a) Write the equation for the predominant reaction of $HC_2O_4^-$ with HSO_3^-. **(1 mark)**

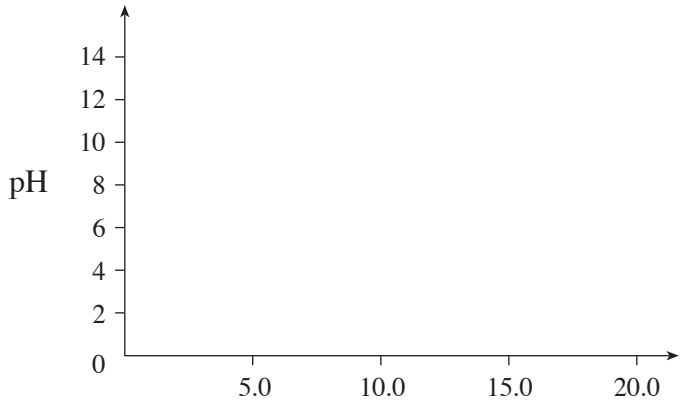
$$HC_2O_4^- \quad + \quad HSO_3^- \quad \rightleftarrows \quad \_\_\_\_\_ \quad + \quad \_\_\_\_\_$$

acid base

b) Identify a Brønsted-Lowry conjugate acid base pair from the above reaction. **(1 mark)**

Acid: _____ Base: _____

7. a) In the space below, sketch the titration curve for the reaction when 0.10 M HCl is added to 10.0 mL of 0.10 M NaOH. **(3 marks)**



b) Describe two changes in the titration curve that would result from using 0.10 M CH_3COOH in place of the HCl. **(2 marks)**

i) _____

ii) _____

8. Calculate the $\left[OH^{-}\right]$ in $0.50\,M\ NH_{3(aq)}$. **(5 marks)**

OVER

9. Balance the following redox reaction in basic solution. **(5 marks)**

$$MnO_4^- + C_2O_4^{2-} \rightarrow MnO_2 + CO_3^{2-} \qquad \text{(basic)}$$

10. a) Draw and label the parts of an operating electrolytic cell during the electrolysis of molten potassium chloride $KCl_{(\ell)}$. **(3 marks)**

b) Define the term *oxidizing agent*. **(1 mark)**

_____

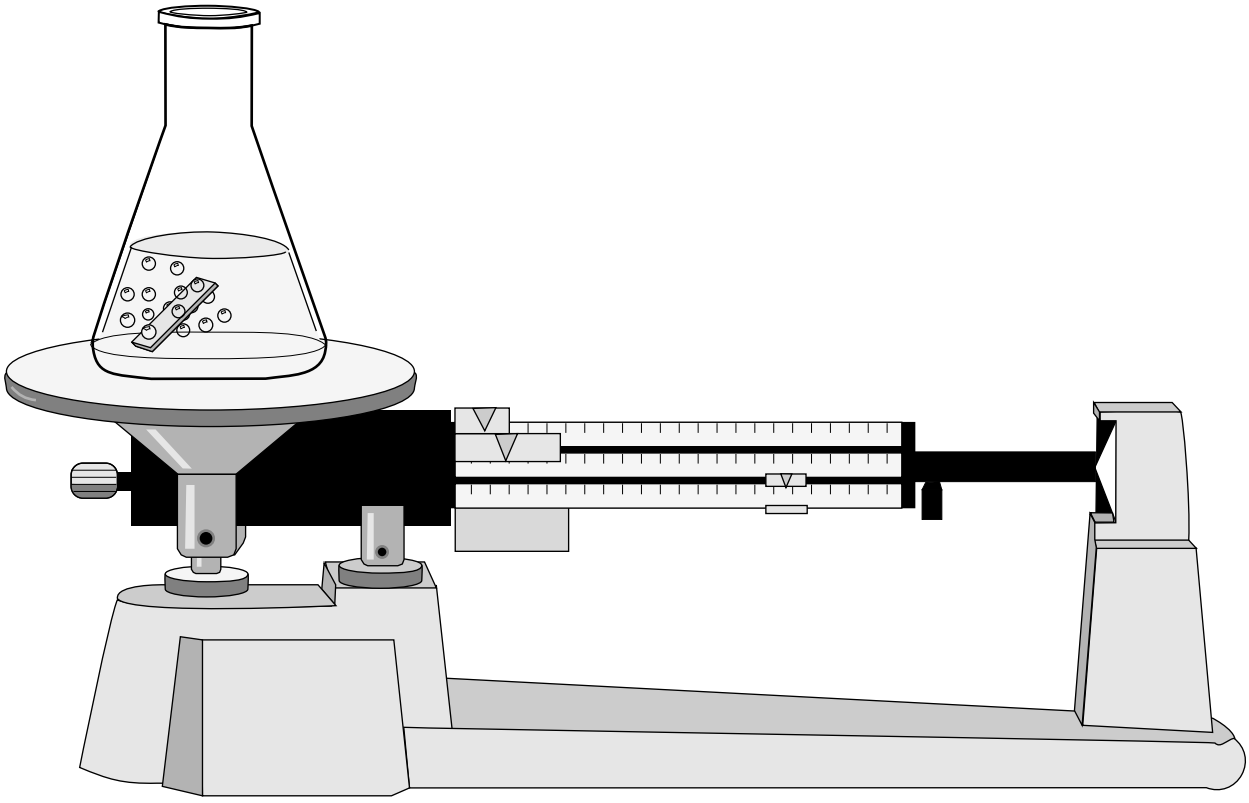
_____

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