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BRITISH COLUMBIA

Chemistry 12

JANUARY 2003

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. .

(3)

Question 7:

7. .

(2)

Question 2:

2. .

(3)

Question 8:

8. .

(2)

Question 3:

3. .

(3)

Question 9:

9. .

(5)

Question 4:

4. .

(3)

Question 10:

10. .

(3)

Question 5:

5. .

(4)

Question 11:

11. .

(4)

Question 6:

6. .

(4)

Question 12:

12. .

(4)

Chemistry 12

JANUARY 2003

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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: 12 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. The calculator **must not** be programmable. Computers, calculators with a QWERTY keyboard or symbolic manipulation abilities, and electronic writing pads will not be allowed. Students must not bring any external devices (peripherals) to support calculators such as manuals, printed or electronic cards, printers, memory expansion chips or cards, CD-ROMS, libraries or external keyboards. 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.

Note that some multiple-choice questions are worth 2 marks.

1. Given the reaction:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + H_2O_{(\ell)} + CO_{2(g)} + \text{heat}$$

Which of the following will cause the reaction rate to increase? **(1 mark)**

A. increasing pressure
B. decreasing pressure
C. increasing temperature
D. decreasing temperature

2. Consider the following reaction:

$$Fe_2O_{3(s)} + 2Al_{(s)} \rightarrow Al_2O_{3(s)} + 2Fe_{(\ell)}$$

If 0.50 mol of Fe is produced in 10.0 sec, what is the rate of consumption of Fe_2O_3 in mol/s ? **(2 marks)**

A. 5.0×10^{-2} mol/s
B. 2.5×10^{-2} mol/s
C. 1.0×10^{-1} mol/s
D. 5.0 mol/s

3. Which of the following would result in a successful collision between reactant particles? **(1 mark)**

A. particles have sufficient KE
B. particles convert all their PE into KE
C. particles are in an excited state and are catalyzed
D. particles have sufficient KE and proper molecular orientation

OVER

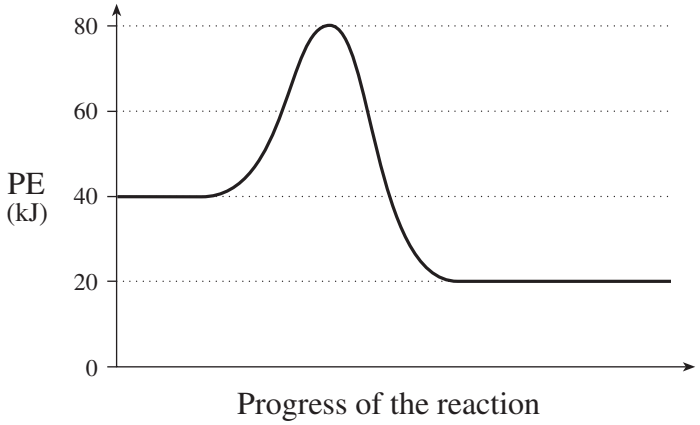
4. Which of the following best describes the E_a of a fast reaction and the stability of its activated complex? **(1 mark)**

	E_a	Activated Complex
A.	small	unstable
B.	small	stable
C.	large	unstable
D.	large	stable

5. How does the addition of a catalyst increase the reaction rate of an endothermic reaction? **(1 mark)**

A. It reduces the ΔH of the reaction.
B. It increases the ΔH of the reaction.
C. It reduces the required activation energy.
D. It causes the reaction to become exothermic.

6. Consider the following PE diagram:



What is the activation energy for the **reverse** reaction? **(1 mark)**

A. −60 kJ
B. −20 kJ
C. +40 kJ
D. +60 kJ

7. Which of the factors below is **not** a condition necessary for equilibrium? **(1 mark)**

A. a closed system
B. a constant temperature
C. equal forward and reverse reaction rates
D. equal concentrations of reactants and products

8. In order for a chemical reaction to go to completion, how must the entropy and enthalpy change? **(1 mark)**

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

9. Consider the following equilibrium system:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad K_{eq} = 1.2 \times 10^4$$

If additional SO_2 is added to the system, what happens to the equilibrium and the value of K_{eq} ? **(1 mark)**

	Equilibrium	K_{eq}
A.	shifts left	decreases
B.	shifts right	increases
C.	shifts right	no change
D.	no change	no change

OVER

10. Consider the following equilibrium system:

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

Determine the changes in reaction rates as a catalyst is added. **(1 mark)**

	Forward Rate	Reverse Rate
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

11. Consider the following equilibrium system:

$$2KClO_{3(s)} \rightleftarrows 2KCl_{(s)} + 3O_{2(g)}$$

Which of the following is the equilibrium constant expression? **(1 mark)**

A. $K_{eq} = [O_2]^3$

B. $K_{eq} = \dfrac{1}{[O_2]^3}$

C. $K_{eq} = \dfrac{[KClO_3]^2}{[KCl]^2[O_2]^3}$

D. $K_{eq} = \dfrac{[KCl]^2[O_2]^3}{[KClO_3]^2}$

12. Consider the following equilibrium:

$$CO_{2(g)} + 2H_2O_{(g)} \rightleftarrows CH_{4(g)} + 2O_{2(g)}$$

Which of the options below indicates that the reactants are favoured? **(1 mark)**

A. K_{eq} is zero.

B. K_{eq} is very large.

C. K_{eq} is slightly less than 1.

D. K_{eq} is slightly greater than 1.

13. Consider the following equilibrium:

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

How are K_{eq} and $[N_2O_4]$ affected by the addition of Ne (an inert gas) into the container at constant volume. **(2 marks)**

	K_{eq}	$[N_2O_4]$
A.	no change	no change
B.	no change	increases
C.	increases	decreases
D.	decreases	increases

14. Consider the following equilibrium:

$$Cl_{2(g)} + 2NO_{(g)} \rightleftarrows 2NOCl_{(g)} \qquad K_{eq} = 5.0$$

At equilibrium, $[Cl_2] = 1.0\,M$ and $[NO] = 2.0\,M$. What is the $[NOCl]$ at equilibrium? **(1 mark)**

A. 0.80 M

B. 0.89 M

C. 4.5 M

D. 10 M

OVER

15. Solid $Ba(OH)_2$ is added to water to prepare a saturated solution.
Which of the following is true for this equilibrium system? **(1 mark)**

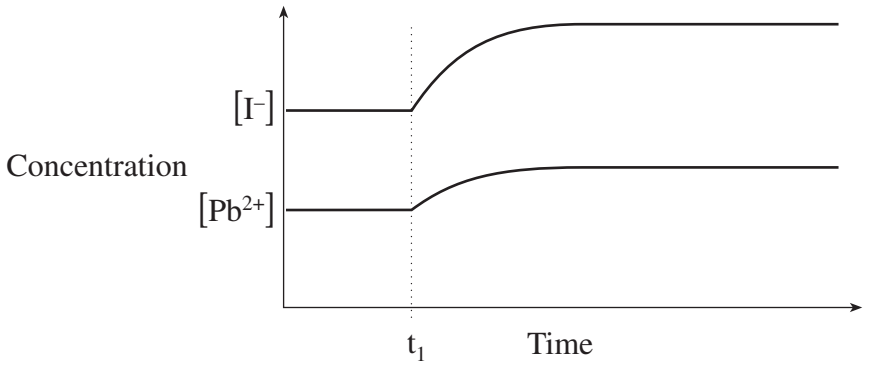
A. $[\text{anion}] = [\text{cation}]$

B. trial K_{sp} is less than K_{sp}

C. blue litmus paper would turn red

D. the rate of dissolving = the rate of crystallization

16. A saturated solution of PbI_2 was subjected to a stress and the following graph was obtained.



Which stress was applied at time t_1 ? **(1 mark)**

A. the addition of PbI_2

B. a temperature change

C. an increase in volume

D. the evaporation of water

17. Which of the following would be true when equal volumes of 0.2 M NaBr and 0.2 M $AgNO_3$ are combined? **(2 marks)**

A. No precipitate forms.

B. A precipitate of AgBr forms.

C. A precipitate of $NaNO_3$ forms.

D. Precipitates of both $NaNO_3$ and AgBr form.

18. Using the solubility table, determine which of the following ions could **not** be used to separate S^{2-} from SO_4^{2-} by precipitation? **(1 mark)**

A. Be^{2+}
B. Ca^{2+}
C. Ba^{2+}
D. Sr^{2+}

19. Which of the following is true when solid Na_2S is added to a saturated solution of CuS and equilibrium is reestablished? **(1 mark)**

A. $\left[S^{2-}\right]$ increases.
B. $\left[Cu^{2+}\right]$ increases.
C. $\left[S^{2-}\right]$ does not change.
D. $\left[Cu^{2+}\right]$ does not change.

20. Which of the following describes the relationship between the solubility product constant $\left(K_{sp}\right)$ and the solubility (s) of PbI_2? **(1 mark)**

A. $K_{sp} = s^2$

B. $K_{sp} = 4s^3$

C. $s = \dfrac{\sqrt[3]{K_{sp}}}{4}$

D. $s = \sqrt{K_{sp}}$

OVER

21. Which of the following saturated solutions will have the lowest $\left[S^{2-}\right]$? **(2 marks)**

A. BaS
B. CaS
C. CuS
D. ZnS

22. What is the solubility of SrF_2 ? **(2 marks)**

A. 3.2×10^{-25} M
B. 1.8×10^{-17} M
C. 4.3×10^{-9} M
D. 1.0×10^{-3} M

23. Which of the following represents the neutralization reaction between $Ca(OH)_{2(s)}$ and $HCl_{(aq)}$? **(1 mark)**

A. $H_2O_{(\ell)} \rightarrow H^+_{(aq)} + OH^-_{(aq)}$
B. $Ca^{2+}_{(aq)} + 2Cl^-_{(aq)} \rightarrow CaCl_{2(s)}$
C. $Ca(OH)_{2(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + 2H_2O_{(\ell)}$
D. $Ca^{2+}_{(aq)} + 2OH^-_{(aq)} + 2H^+_{(aq)} + 2Cl^-_{(aq)} \rightarrow CaCl_{2(s)} + 2H_2O_{(\ell)}$

24. Which of the following solutions will have the lowest electrical conductivity? **(1 mark)**

A. 1.0 M HI
B. 1.0 M H_2S
C. 1.0 M NaOH
D. 1.0 M $NaNO_3$

25. Consider the following equilibrium:

$$HCO_3^- + H_3O^+ \rightleftarrows H_2CO_3 + H_2O$$

Which of the following statements is true? **(2 marks)**

A. Products are favoured because H_2O is a stronger acid than H_2CO_3
B. Products are favoured because H_3O^+ is a stronger acid than H_2CO_3
C. Reactants are favoured because HCO_3^- is a stronger base than H_2O
D. Reactants are favoured because H_3O^+ is a stronger acid than H_2CO_3

26. Which of the following factors of an acidic solution would affect its pH? **(1 mark)**

I.	the strength of the acid
II.	the concentration of the acid
III.	the temperature

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

27. Consider the following equilibrium:

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

What changes occur to $\left[H_3O^+\right]$ and pH when NaOH is added? **(2 marks)**

A. $\left[H_3O^+\right]$ increases and pH increases.
B. $\left[H_3O^+\right]$ increases and pH decreases.
C. $\left[H_3O^+\right]$ decreases and pH increases.
D. $\left[H_3O^+\right]$ decreases and pH decreases.

OVER

28. The ionization of water is endothermic. How is K_w related to the temperature of water? **(1 mark)**

A. K_w increases as temperature increases.
B. K_w decreases as temperature increases.
C. K_w increases as temperature decreases.
D. K_w remains constant as temperature decreases.

29. Which of the following represents the dissociation equation of a salt in water? **(1 mark)**

A. $KCl_{(s)} \rightarrow K^+_{(aq)} + Cl^-_{(aq)}$
B. $Ca^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow CaSO_{4(s)}$
C. $HCl_{(aq)} + KOH_{(aq)} \rightarrow KCl_{(aq)} + H_2O_{(\ell)}$
D. $2Na_{(s)} + 2H_2O_{(\ell)} \rightarrow 2NaOH_{(aq)} + H_{2(g)}$

30. Which of the following represents the equilibrium constant expression for the hydrolysis reaction that occurs in $NaF_{(aq)}$? **(1 mark)**

A. $K_b = \dfrac{[HF][OH^-]}{[F^-]}$

B. $K_a = \dfrac{[F^-][H_3O^+]}{[HF]}$

C. $K_{eq} = \dfrac{[Na^+][F^-]}{[NaF]}$

D. $K_w = [H_3O^+][OH^-]$

31. Which of the following salt solutions will be acidic? **(1 mark)**

A. $KClO_4$
B. NH_4Br
C. $NaHCO_3$
D. $Na_2C_2O_4$

32. The indicator phenol red will be red in which of the following solutions? **(1 mark)**

A. 1.0 M HF
B. 1.0 M HBr
C. 1.0 M NH_4Cl
D. 1.0 M Na_2CO_3

33. Which of the following chemical indicators has a $K_a = 2.5 \times 10^{-5}$? **(1 mark)**

A. methyl orange
B. phenolphthalein
C. thymolphthalein
D. bromcresol green

34. *At a certain point in a strong acid-strong base titration, the moles of H^+ are equal to the moles of OH^-.* This is a definition of which of the following? **(1 mark)**

A. the end point
B. the titration point
C. the transition point
D. the equivalence point

35. A 25.0 mL sample of $H_2SO_{4(aq)}$ is titrated with 15.5 mL of 0.50 M $NaOH_{(aq)}$. What is the concentration of the $H_2SO_{4(aq)}$? **(2 marks)**

A. 0.078 M
B. 0.16 M
C. 0.31 M
D. 0.62 M

36. What is the complete ionic equation for the neutralization of 0.1 M $Sr(OH)_{2(aq)}$ with 0.1 M $H_2SO_{4(aq)}$? **(2 marks)**

A. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)}$
B. $Sr^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow SrSO_{4(s)}$
C. $Sr^{2+}_{(aq)} + 2\,OH^-_{(aq)} + 2H^+_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow SrSO_{4(s)} + 2H_2O_{(\ell)}$
D. $Sr^{2+}_{(aq)} + 2\,OH^-_{(aq)} + 2H^+_{(aq)} + SO_4{}^{2-}_{(aq)} \rightarrow Sr^{2+}_{(aq)} + SO_4{}^{2-}_{(aq)} + 2H_2O_{(\ell)}$

OVER

37. Carbon dioxide gas in the atmosphere dissolves in normal rainwater. This causes normal rainwater to **(1 mark)**

A. be slightly basic.
B. have a pH slightly less than 7.0 .
C. be unaffected and remain neutral.
D. have a pH slightly greater than 7.0 .

38. Consider the following equation:

$$16H^+ + 2MnO_4^- + 5C_2O_4^{2-} \rightarrow 10\,CO_2 + 2Mn^{2+} + 8H_2O$$

Identify the chemical species which is reduced. **(1 mark)**

A. H^+
B. Mn^{2+}
C. MnO_4^-
D. $C_2O_4^{2-}$

39. Consider the following equation:

$$H_3AsO_4 + 4Zn + 8H^+ \rightarrow AsH_3 + 4Zn^{2+} + 4H_2O$$

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

A. Oxygen is reduced.
B. Arsenic is oxidized.
C. Zinc is the oxidizing agent.
D. The reaction is a redox reaction.

40. What is the oxidation number of iron in magnetite, Fe_3O_4 ? **(1 mark)**

A. $+\frac{4}{3}$
B. $+2$
C. $+\frac{8}{3}$
D. $+3$

41. Consider the following spontaneous reactions:

$$3Cd^{2+} + 2Np \rightarrow 3Cd + 2Np^{3+}$$

$$Cd + Pd^{2+} \rightarrow Pd + Cd^{2+}$$

$$Np^{3+} + Ce \rightarrow Np + Ce^{3+}$$

Which is the strongest oxidizing agent? **(2 marks)**

A. Cd^{2+}
B. Ce^{3+}
C. Np^{3+}
D. Pd^{2+}

42. The volumetric analysis of hydrogen peroxide is often carried out by titrating with aqueous $KMnO_4$ in an acidic solution. The unbalanced formula equation for the reaction is:

$$H_2O_2 + KMnO_4 + H_2SO_4 \rightarrow K_2SO_4 + MnSO_4 + H_2O + O_2$$

Which of the following is the correct set of balancing coefficients? **(2 marks)**

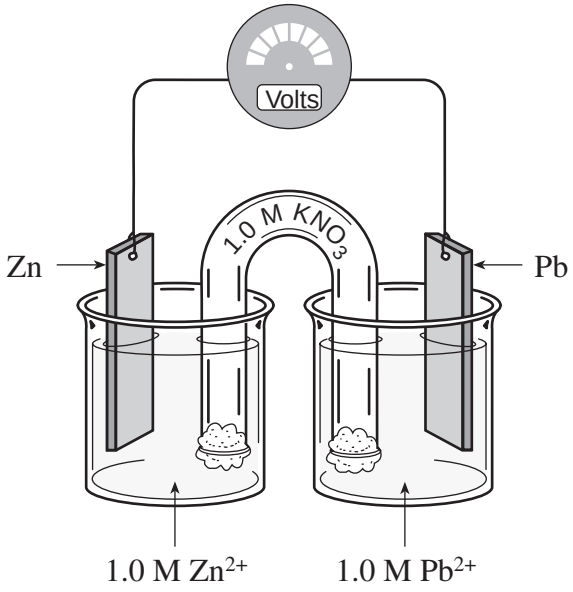
A. 1, 1, 1, 1, 1, 1, 1
B. 1, 2, 3, 1, 2, 4, 3
C. 2, 5, 3, 2, 1, 8, 5
D. 5, 2, 3, 1, 2, 8, 5

43. Which of the following would **not** be found in **all** electrochemical cells? **(1 mark)**

A. ions
B. an anode
C. a cathode
D. two beakers

OVER

Use the following diagram to answer questions 44 and 45.



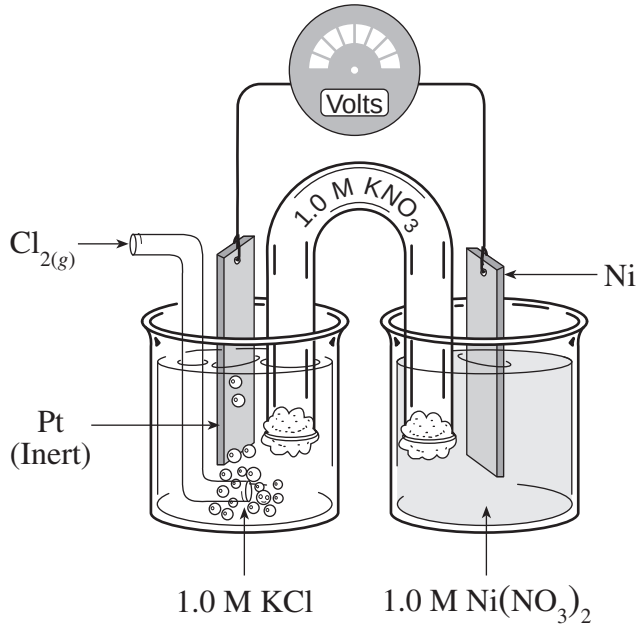
44. As this cell operates, the cations move towards the **(1 mark)**

A. Pb electrode and the electrode gains mass.
B. Pb electrode and the electrode loses mass.
C. Zn electrode and the electrode gains mass.
D. Zn electrode and the electrode loses mass.

45. As the cell operates, the electrons flow towards the **(1 mark)**

A. Zn electrode and the cell voltage increases over time.
B. Pb electrode and the cell voltage decreases over time.
C. Zn electrode and the cell voltage decreases over time.
D. Pb electrode and the cell voltage remains constant over time.

46. Consider the following electrochemical cell:



What is the E° for this cell? **(1 mark)**

A. −1.62 V
B. −1.10 V
C. +1.10 V
D. +1.62 V

47. An aqueous solution of $CuSO_4$ is electrolyzed using copper electrodes. Which of the following would correctly describe the changes in the mass of each electrode and the $\left[Cu^{2+}\right]$ in solution? **(2 marks)**

	Mass of Anode	Mass of Cathode	$\left[Cu^{2+}\right]$
A.	increases	increases	increases
B.	increases	decreases	stays the same
C.	decreases	increases	stays the same
D.	decreases	decreases	increases

OVER

48. Which of the following are produced at the anode and cathode in the electrolysis of aqueous potassium sulfate using carbon electrodes? **(1 mark)**

	Anode	Cathode
A.	potassium	oxygen
B.	hydrogen	oxygen
C.	oxygen	hydrogen
D.	sulfur	potassium

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

PART B: WRITTEN RESPONSE

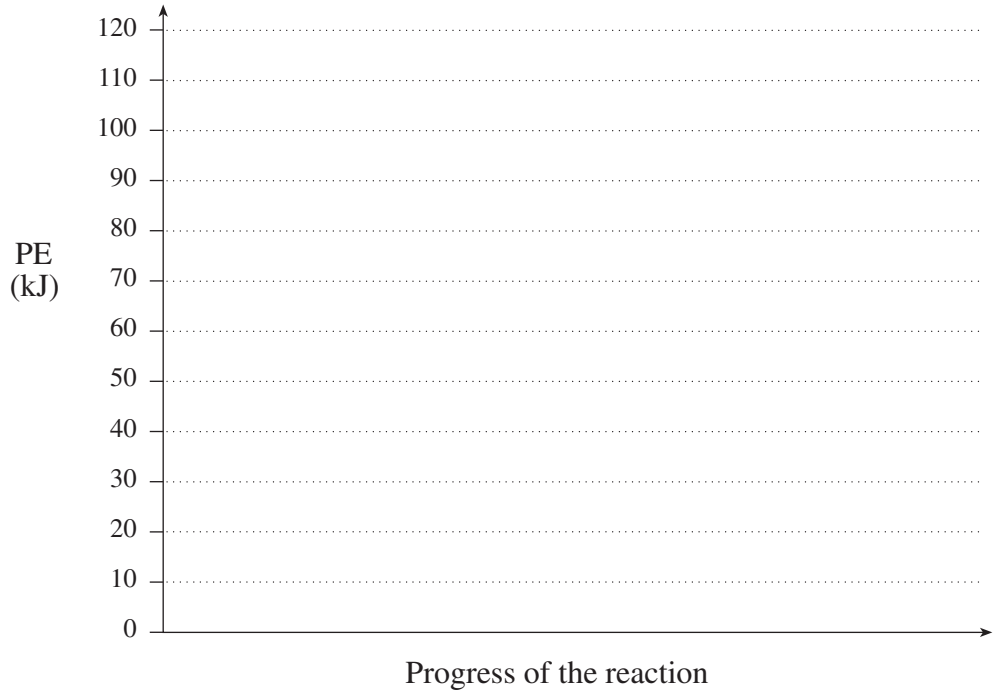
Value: 40 marks **Suggested Time: 50 minutes**

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 calculations, full marks will NOT be given for providing only an answer.**

1. Using the axes below, sketch a PE diagram for the reacting system where: **(3 marks)**

$$\Delta H = -30\,kJ/mol$$

$$E_a = 50\,kJ/mol$$



OVER

2. Consider the following reaction mechanism:

Step 1	$2NO \rightarrow N_2O_2$
Step 2	$N_2O_2 + H_2 \rightarrow N_2O + H_2O$
Step 3	$N_2O + H_2 \rightarrow N_2 + H_2O$

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

Overall Reaction: _____

b) Identify a reaction intermediate. **(1 mark)**

_____

3. Consider the following equilibrium:

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

K_{eq}	Temperature
1.78×10^{-3}	800°C
4.68×10^{-2}	1000°C

Is the forward reaction in this equilibrium exothermic or endothermic?
Explain your answer. **(3 marks)**

_____

_____

_____

_____

4. Consider the following equilibrium:

$$CO_{(g)} + Cl_{2(g)} \rightleftarrows COCl_{2(g)}$$

At equilibrium, the system contains 2.00 mol CO, 1.00 mol Cl_2 and 0.200 mol $COCl_2$ in a 2.0 L container. Calculate the value of K_{eq}. **(3 marks)**

5. Calculate the mass of NaI necessary to begin precipitation of Cu^+ from a 250.0 mL sample of 0.010 M $CuNO_3$. **(4 marks)**

OVER

6. When a solution of $Na_2CO_{3(aq)}$ is mixed with a solution of $Ca(NO_3)_{2(aq)}$ a precipitate forms.

   a) Write the net ionic equation for the precipitation reaction. **(1 mark)**

   b) Explain what happens to the precipitate when HCl is added. **(3 marks)**

7. Write a chemical reaction showing an amphiprotic anion reacting as a base in water. **(2 marks)**

8. Calculate the pOH of $0.25\,M$ $Sr(OH)_2$. **(2 marks)**

9. A $2.00\,M$ diprotic acid has a pH of 0.50. Calculate its K_a value. **(5 marks)**

OVER

10. The following two experiments were conducted:

Titration A: A strong acid was titrated with a strong base.

Titration B: A weak acid was titrated with a strong base.

a) How does the pH at the equivalence point of Titration B compare with the pH at the equivalence point of Titration A? **(1 mark)**

_____

_____

b) Explain your answer to a). **(2 marks)**

_____

_____

11. Balance the following redox reaction. **(4 marks)**

$$Sb + NO_3^- \rightarrow Sb_2O_5 + NO \qquad \text{(acidic)}$$

12. A 1.0 M HCl solution is electrolyzed using a copper anode and an inert carbon cathode. Predict the half-reactions that will occur and describe what you would observe at each electrode. **(4 marks)**

Anode half-reaction: _____

Anode observation: _____

_____

Cathode half-reaction: _____

Cathode observation: _____

_____

END OF EXAMINATION

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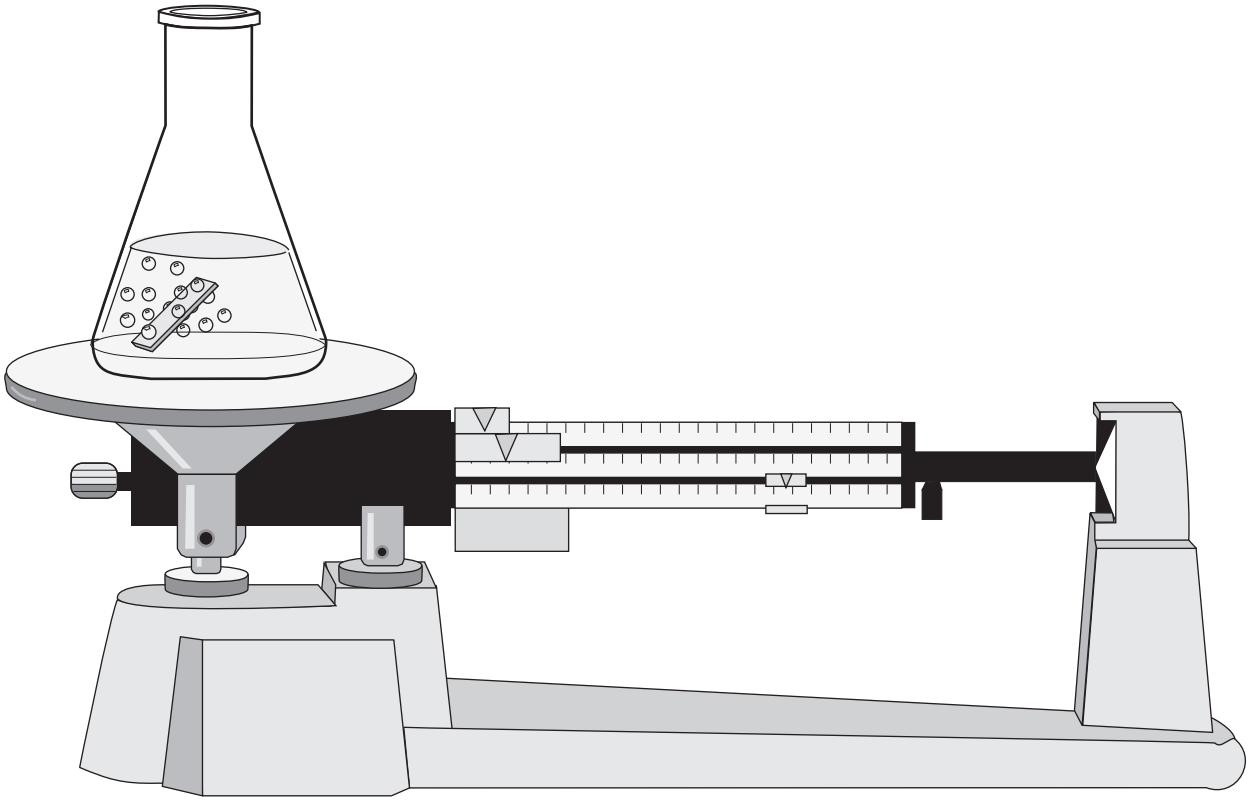
Data Booklet

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 — Atomic Number
Si — Symbol
Silicon — Name
28.1 — 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