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BRITISH COLUMBIA

Chemistry 12

JUNE 2004

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

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ . (5) ☐ NR ☐

Question 2

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ . (5) ☐ NR ☐

Question 3

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Question 4

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Question 5

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Question 6

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ . (5) ☐ NR ☐

Question 7

0 ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ . (5) ☐ NR ☐

Question 8

0 ☐ 1 ☐ 2 ☐ 3 ☐ . (5) ☐ NR ☐

Chemistry 12

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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:	60 multiple-choice questions	60	80
PART B:	8 written-response questions	30	40
	Total:	**90 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 be capable of performing graphing functions. 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. Students may have more than one calculator available during the examination, of which one may be a scientific calculator. 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.

   Calculators must not have any information programmed into memory that would not be acceptable in paper form. Specifically, calculators must not have any built-in notes, definitions, or libraries. There is no requirement to clear memories at the beginning of the examination but the use of calculators with built-in notes is equivalent to the use of notes in paper form. Any student deemed to have cheated on a provincial examination will receive a "0" on that examination and will be permanently disqualified from the Provincial Examination Scholarship Program.

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PART A: MULTIPLE CHOICE

Value: 60 marks **Suggested Time: 80 minutes**

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

1. Which of the following could represent the units for reaction rate?

   A. g/mL
   B. g/min
   C. g/mol
   D. mol/L

2. Consider the following reaction:

$$Zn_{(s)} + 2HCl_{(aq)} \rightarrow ZnCl_{2(aq)} + H_{2(g)}$$

   Which of the following would increase the reaction rate?

   A. an increase in pressure
   B. an increase in temperature
   C. an increase in the concentration of H_2
   D. an increase in the concentration of $ZnCl_2$

3. Consider the following reaction:

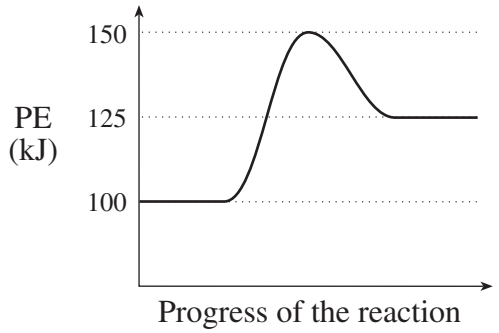
$$H_{2(g)} + I_{2(g)} \rightarrow 2HI_{(g)}$$

   Which of the following is true of the activated complex relative to the reactants?

	KE	Stability
A.	high	stable
B.	low	stable
C.	high	unstable
D.	low	unstable

OVER

4. Consider the following PE diagram:



Which of the following is true for the forward reaction?

	ΔH (kJ)	PE of Activated Complex (kJ)
A.	–25	50
B.	–25	150
C.	+25	50
D.	+25	150

5. Which of the following could describe a catalyst?

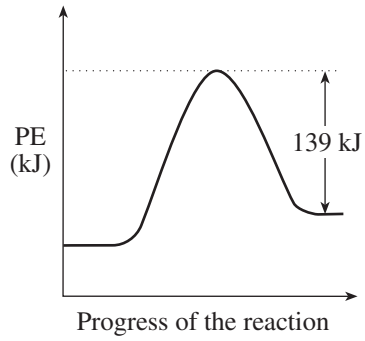
A. A substance that increases the reaction time.
B. A substance that provides an alternate mechanism with a higher activation energy.
C. A substance that is formed in one step and used up in a subsequent step in a reaction mechanism.
D. A substance that is used up in one step and reformed in a subsequent step in a reaction mechanism.

6. The following forward reaction has an $E_a = 167\,kJ$:

$$28\,kJ + H_{2(g)} + I_{2(g)} \rightleftarrows 2HI_{(g)}$$

Which of the PE diagrams below represents this reaction?

A.



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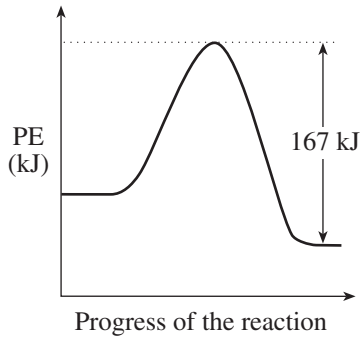
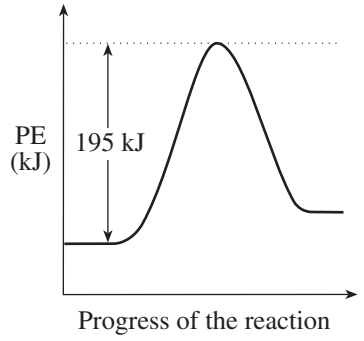
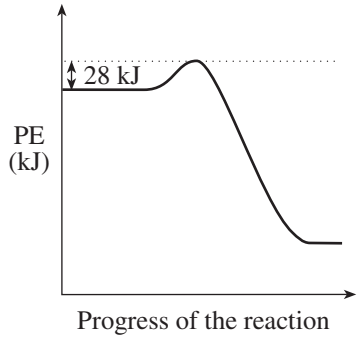


C.



D.



7. A small amount of HCl is added to the following equilibrium system:

$$2CrO_4^{2-}{}_{(aq)} + 2H^+_{(aq)} \rightleftarrows Cr_2O_7^{2-}{}_{(aq)} + H_2O_{(\ell)}$$

How do the $\left[CrO_4^{2-}\right]$ and the reverse reaction rate change as equilibrium is re-established?

	$\left[CrO_4^{2-}\right]$	Reverse Rate
A.	increases	increases
B.	increases	decreases
C.	decreases	decreases
D.	decreases	increases

OVER

Use the following equilibrium to answer questions 8 and 9.

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

colourless brown

8. If N_2O_4 is placed in a flask at a constant temperature, which of the following is true as the system approaches equilibrium?

   A. The colour gets darker as $[NO_2]$ increases.
   B. The colour gets lighter as $[NO_2]$ decreases.
   C. The colour gets darker as $[N_2O_4]$ increases.
   D. The colour gets lighter as $[N_2O_4]$ decreases.

9. The system above reaches equilibrium. Considering enthalpy and entropy factors, which of the following is true with respect to the forward reaction?

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

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10. In which of the following reactions do the tendencies for minimum enthalpy and maximum entropy both favour reactants?

   A. $3O_{2(g)} \overset{?}{\rightleftarrows} 2O_{3(g)} \qquad \Delta H = +285\,kJ$

   B. $N_{2(g)} + 3H_{2(g)} \overset{?}{\rightleftarrows} 2NH_{3(g)} \qquad \Delta H = -92\,kJ$

   C. $2BrCl_{(g)} \overset{?}{\rightleftarrows} Br_{2(g)} + Cl_{2(g)} \qquad \Delta H = -29.3\,kJ$

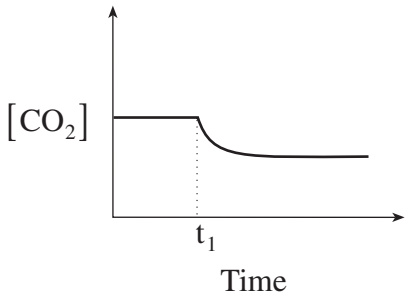
   D. $CaCO_{3(s)} \overset{?}{\rightleftarrows} CaO_{(s)} + CO_{2(g)} \qquad \Delta H = +175\,kJ$

11. Consider the following equilibrium:

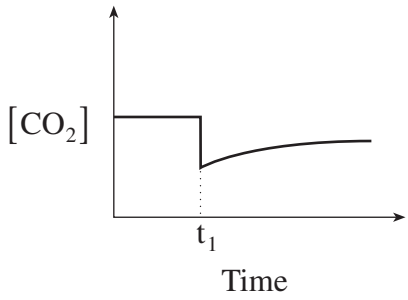
$$CaCO_{3(s)} \rightleftarrows CaO_{(s)} + CO_{2(g)} \qquad \Delta H = +175\,kJ$$

Which of the following diagrams best represents the change in the concentration of CO_2 as temperature is decreased at time t_1 ?

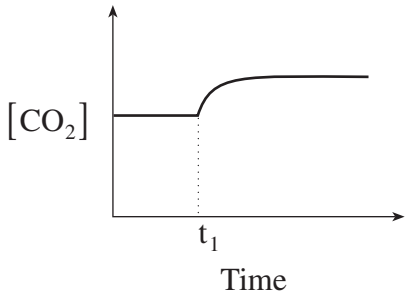
A.



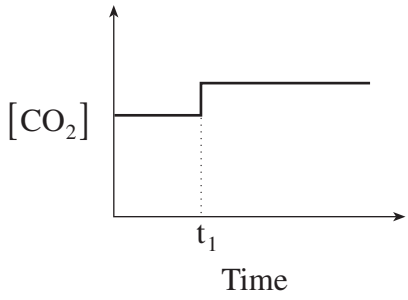
B.



C.



D.



12. ~~Consider the following equilibrium:~~

$$\sout{2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)}}$$

~~If some CO is added, the equilibrium shifts right. How does reaction kinetics explain this shift to the right?~~

A. ~~The reverse rate decreases.~~
B. ~~The forward rate increases.~~
C. ~~The pressure of the system increases.~~
D. ~~The concentration of CO has increased.~~

OVER

13. The Haber Process is used to produce ammonia commercially according to the following equilibrium:

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

Which of the following conditions will produce the highest yield of ammonia?

A. increase temperature and increase pressure
B. increase temperature and decrease pressure
C. decrease temperature and increase pressure
D. decrease temperature and decrease pressure

14. Consider the following equilibrium:

$$Cr_2O_7^{2-}{}_{(aq)} + 2\,OH^-{}_{(aq)} \rightleftarrows 2CrO_4^{2-}{}_{(aq)} + H_2O_{(\ell)} \qquad K_{eq} = 4.14$$

The concentration of ions at equilibrium was measured at a specific temperature and found to be $\left[Cr_2O_7^{2-}\right] = 0.100\,\text{M}$ and $\left[OH^-\right] = 0.020\,\text{M}$. What is the equilibrium $\left[CrO_4^{2-}\right]$?

A. $1.7 \times 10^{-4}\,\text{M}$
B. $3.1 \times 10^{-3}\,\text{M}$
C. $1.3 \times 10^{-2}\,\text{M}$
D. $2.0 \times 10^{-1}\,\text{M}$

15. In which of the following equilibria does the concentration of reactants equal the concentration of products?

A. $N_2O_{4(g)} \rightleftarrows 2NO_{2(g)} \qquad K_{eq} = 0.71$
B. $H^+{}_{(aq)} + OH^-{}_{(aq)} \rightleftarrows H_2O_{(\ell)} \qquad K_{eq} = 1.0 \times 10^{14}$
C. $CO_{2(g)} + H_{2(g)} \rightleftarrows CO_{(g)} + H_2O_{(g)} \qquad K_{eq} = 0.279$
D. $SnO_{2(s)} + 2H_{2(g)} \rightleftarrows Sn_{(s)} + 2H_2O_{(g)} \qquad K_{eq} = 1.00$

16. Consider the following equilibrium:

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

At equilibrium, 4.0×10^{-2} mol H_2, 4.0×10^{-2} mol CO, 1.0×10^{-2} mol H_2O and 1.0×10^{-2} mol C were present in a 1.0 L container. What is the value of K_{eq} ?

A. 0.063
B. 0.16
C. 6.3
D. 16

17. Consider the following equilibrium:

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

Initially, 0.12 M CO_2 and 0.20 M CF_4 are placed in a container. At equilibrium, it is found that the $[COF_2]$ is 0.040 M. What is the value of K_{eq} ?

A. 0.089
B. 0.45
C. 8.0
D. 11

18. Which of the solutes below can form an ionic solution with the highest conductivity?

A. PbS
B. CH_3Cl
C. $NaNO_3$
D. CH_3COOH

OVER

19. The following data was collected to determine the solubility of a substance:

Mass of solute dissolved	5.00 g
Volume of solvent	250.0 mL
Molar mass of solute	100.0 g/mol
Molar mass of solvent	20.0 g/mol

Which of the following best describes its solubility?

A. 2.00×10^{-2} g/mL
B. 5.00×10^{-2} mol
C. 0.250 mol
D. 1.00 mol/L

20. Which value best represents the total ion concentration when 0.10 moles of K_3PO_4 is present in 0.5 L of solution?

A. 0.1 M
B. 0.2 M
C. 0.4 M
D. 0.8 M

21. What will happen when equal volumes of 0.20 M $(NH_4)_2S$ and 0.20 M $Sr(OH)_2$ are mixed?

A. SrS precipitates.
B. NH_4OH precipitates.
C. Both NH_4OH and SrS precipitate.
D. No precipitate forms.

22. Which anion would be most effective in removing the cations responsible for hard water?

A. S^{2-}
B. Cl^-
C. PO_4^{3-}
D. SO_4^{2-}

23. Which of the following is the K_{sp} expression for barium phosphate?

A. $K_{sp} = \left[Ba^{2+}\right]\left[PO_4{}^{3-}\right]$

B. $K_{sp} = \left[Ba^{2+}\right]^3\left[PO_4{}^{3-}\right]^2$

C. $K_{sp} = \left[3Ba^{2+}\right]\left[2PO_4{}^{3-}\right]$

D. $K_{sp} = \left[3Ba^{2+}\right]^3\left[2PO_4{}^{3-}\right]^2$

24. The solubility of $Mg(OH)_2$ is found to be 1.2×10^{-4} M . What is its K_{sp} ?

A. 6.9×10^{-12}

B. 1.7×10^{-12}

C. 1.4×10^{-8}

D. 1.2×10^{-4}

25. Which of the following is true for the salt SrF_2 at 25°C ?

A. It has a high solubility.

B. It will not dissolve at all.

C. Its solubility is 1.6×10^{-3} M.

D. Its solubility is 1.0×10^{-3} M.

26. Which of the following ions could be used in the lowest concentration to remove Ag^+ ions from a polluted water sample?

A. I^-

B. Br^-

C. $BrO_3{}^-$

D. $CO_3{}^{2-}$

OVER

27. Which of the following best describes an acidic solution?

	Litmus Colour	Reaction with Zn
A.	red	reaction
B.	red	no reaction
C.	blue	no reaction
D.	blue	reaction

28. Identify the common acid found in the stomach.

A. nitric acid
B. sulphuric acid
C. perchloric acid
D. hydrochloric acid

29. Consider the following equilibrium:

$$HCO_3^- + H_2PO_4^- \rightleftarrows HPO_4^{2-} + H_2CO_3$$

What are the Brønsted-Lowry acids in this equilibrium?

A. HCO_3^- and H_2CO_3
B. HCO_3^- and HPO_4^{2-}
C. $H_2PO_4^-$ and H_2CO_3
D. $H_2PO_4^-$ and HPO_4^{2-}

30. Which of the following solutions would typically show the greatest electrical conductivity?

A. 1.0 M weak acid
B. 0.8 M weak base
C. 0.5 M strong acid
D. 0.1 M strong base

31. ~~Given a 1.0 M solution of HI, which sequence best describes the equilibrium concentration of the substances in the solution?~~

A. ~~$[H_3O^+] > [I^-] > [OH^-] > [HI]$~~
B. ~~$[HI] > [H_3O^+] > [I^-] > [OH^-]$~~
C. ~~$[HI] > [H_3O^+] = [I^-] > [OH^-]$~~
D. ~~$[H_3O^+] > [HI] > [I^-] > [OH^-]$~~

32. Which of the following are amphiprotic in aqueous solutions?

I.	H_3BO_3
II.	$H_2BO_3^-$
III.	HBO_3^{2-}
IV.	BO_3^{3-}

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

33. What happens to the ion concentrations in water when a small amount of $HCl_{(aq)}$ is added?

A. $[H_3O^+] = [OH^-] = 1.0 \times 10^{-7}\ M$
B. $[H_3O^+]$ and $[OH^-]$ both increase
C. $[H_3O^+]$ increases and $[OH^-]$ decreases
D. $[H_3O^+]$ increases and $[OH^-]$ is unchanged

OVER

34. Which of the following is a typical pH value for dishwashing solutions?

A. 2.0
B. 4.0
C. 10.0
D. 14.0

35. What is the pOH of 0.05 M $Sr(OH)_2$?

A. 1.0
B. 1.3
C. 12.7
D. 13.0

36. Consider the following equilibrium:

$$CH_3NH_{2(aq)} + H_2O_{(\ell)} \rightleftarrows CH_3NH_3^+{}_{(aq)} + OH^-{}_{(aq)}$$

Which of the following is true?

A. $K_{eq} = \dfrac{\left[CH_3NH_3^+\right]\left[OH^-\right]}{\left[CH_3NH_2\right]\left[H_2O\right]}$

B. $K_a = \dfrac{\left[CH_3NH_3^+\right]\left[OH^-\right]}{\left[CH_3NH_2\right]}$

C. $K_b = \dfrac{\left[CH_3NH_3^+\right]\left[OH^-\right]}{\left[CH_3NH_2\right]}$

D. $K_{sp} = \left[CH_3NH_3^+\right]\left[OH^-\right]$

37. What is the K_b value for $H_2PO_4^-$?

A. 1.3×10^{-12}
B. 6.2×10^{-8}
C. 1.6×10^{-7}
D. 7.5×10^{-3}

38. Which of the following is the net ionic equation that describes the hydrolysis that occurs in a K_2CO_3 solution?

A. $2K^+_{(aq)} + CO_3^{2-}{}_{(aq)} \rightleftarrows K_2CO_{3(s)}$
B. $K_2CO_{3(aq)} \rightleftarrows 2K^+_{(aq)} + CO_3^{2-}{}_{(aq)}$
C. $CO_3^{2-}{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows HCO_3^-{}_{(aq)} + OH^-_{(aq)}$
D. $K_2CO_{3(aq)} + 2H_2O_{(\ell)} \rightleftarrows H_2CO_{3(aq)} + 2K^+_{(aq)} + 2OH^-_{(aq)}$

39. Which of the following amphiprotic ions will act predominantly as a base in solution?

A. HSO_3^-
B. HSO_4^-
C. HPO_4^{2-}
D. $H_2PO_4^-$

40. Consider the indicator equilibrium:

$$\underset{\text{yellow}}{HIn} + H_2O \rightleftarrows H_3O^+ + \underset{\text{red}}{In^-}$$

Which of the following is true about the transition point of this indicator?

A. pH = 7.0
B. $[HIn] = [In^-]$
C. $[HIn] > [In^-]$
D. moles of H_3O^+ = moles of In^-

OVER

41. What is one of the K_a values for thymol blue?

A. 2×10^{-9}
B. 2×10^{-7}
C. 1×10^{-7}
D. 6×10^{-2}

42. A $25.0\,mL$ sample of a diprotic weak acid is titrated with $20.2\,mL$ of $0.10\,M$ NaOH. What is the concentration of the acid?

A. $0.040\ M$
B. $0.080\ M$
C. $0.16\ M$
D. $0.12\ M$

43. Which of the following is the complete ionic equation for the titration of $HCl_{(aq)}$ with $KOH_{(aq)}$?

A. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)}$
B. $HCl_{(aq)} + KOH_{(aq)} \rightarrow KCl_{(aq)} + H_2O_{(\ell)}$
C. $H^+_{(aq)} + Cl^-_{(aq)} + K^+_{(aq)} + OH^-_{(aq)} \rightarrow KCl_{(aq)} + H_2O_{(\ell)}$
D. $H^+_{(aq)} + Cl^-_{(aq)} + K^+_{(aq)} + OH^-_{(aq)} \rightarrow K^+_{(aq)} + Cl^-_{(aq)} + H_2O_{(\ell)}$

44. What is always true about the pH at the equivalence point when a weak acid is titrated with a strong base?

A. $pH < 6.8$
B. $pH > 7.0$
C. $pH = 7.0$
D. $pH = 8.8$

45. What happens to the pH of a buffer solution if a small amount of base is added?

A. The pH remains constant.
B. The pH increases slightly.
C. The pH decreases slightly.
D. The pH decreases significantly.

46. What would be a reasonable $\left[H_3O^+\right]$ value for a sample of rainwater to be classified as *acid rain*?

A. $1.58 \times 10^{-8}\,M$

B. $3.16 \times 10^{-7}\,M$

C. $6.31 \times 10^{-5}\,M$

D. $1.00 \times 10^{-1}\,M$

47. Consider the following redox equation:

$$MnO_4^- + 5Fe^{2+} + 8H^+ \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$$

Which of the following statements is **false**?

A. Iron is oxidized.
B. Hydrogen is reduced.
C. Manganese is reduced.
D. The equation is balanced.

48. Consider the following unbalanced redox equation:

$$Pt + NO_3^- + Cl^- \rightarrow PtCl_6^{2-} + NO + H_2O$$

Which chemical species is oxidized?

A. Pt

B. Cl^-

C. H_2O

D. NO_3^-

49. What is the oxidation number of carbon in the ethanoate ion $C_2H_3O_2^-$?

A. -1

B. 0

C. $+\frac{1}{2}$

D. $+1$

OVER

50. What reaction will occur when a solution containing $1.0\,M\ MgSO_4$ and $1.0\,M\ CoCl_2$ is stored in a galvanized (Zn coated) bucket?

A. $Mg_{(s)} + Cl_{2(g)} \rightarrow MgCl_2$

B. $Co^{2+} + SO_4^{2-} \rightarrow CoSO_{4(s)}$

C. $Co^{2+} + Zn_{(s)} \rightarrow Zn^{2+} + Co_{(s)}$

D. $Mg^{2+} + Zn_{(s)} \rightarrow Zn^{2+} + Mg_{(s)}$

51. When the skeletal equation $Br_2 \rightarrow BrO_3^-$ is balanced in acidic solution, H_2O, H^+ and e^- will appear. Which of the following are the correct balancing coefficients?

	H_2O	H^+	e^-
A.	3	3	2
B.	6	6	4
C.	6	6	5
D.	6	12	10

52. Consider the following balanced redox equation in acidic solution:

$$5H_2O + 2CoCl_2 + OCl^- \rightarrow 2Co(OH)_3 + 5Cl^- + 4H^+$$

Which of the following describes the amounts and locations of OH^- and H_2O if the equation is balanced in basic solution?

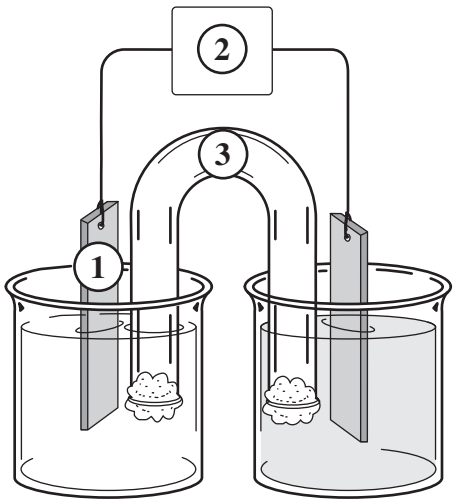
A. $1\,H_2O$ on the left and no OH^-

B. $1\,H_2O$ on the left and $4\,OH^-$ on the left

C. $5\,H_2O$ on the left and $4\,OH^-$ on the left

D. $1\,H_2O$ on the left and $4\,OH^-$ on the right

53. Consider the numbered components in the following diagram:

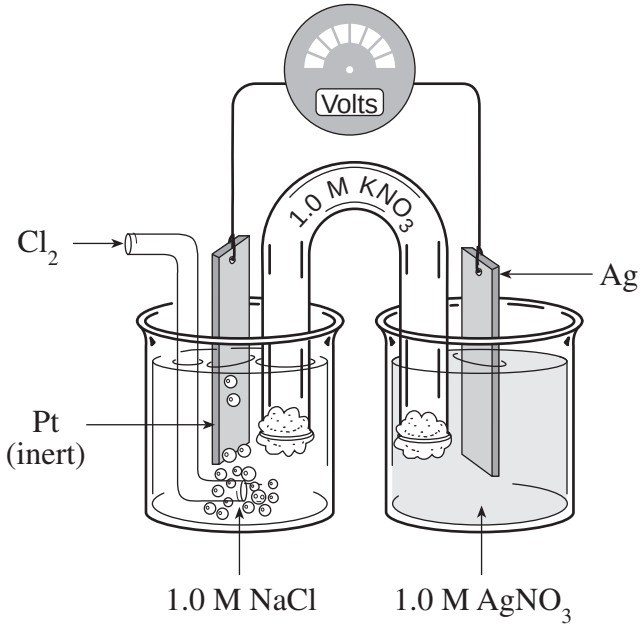


Which of the following would best describe the components of this electrochemical cell?

	Component 1	Component 2	Component 3 (Contents)
A.	non-metal	power supply	$NaNO_{3(aq)}$
B.	metal	light bulb	$NaNO_{3(aq)}$
C.	metal	voltmeter	$CH_3OH_{(aq)}$
D.	metal	power supply	$CH_3OH_{(aq)}$

OVER

Use the following diagram to answer questions 54 to 56.



54. Which of the following represents the anode half-cell reaction?

A. $Ag \rightarrow Ag^+ + e^-$
B. $Ag^+ + e^- \rightarrow Ag$
C. $Cl_2 + 2e^- \rightarrow 2Cl^-$
D. $2Cl^- \rightarrow Cl_2 + 2e^-$

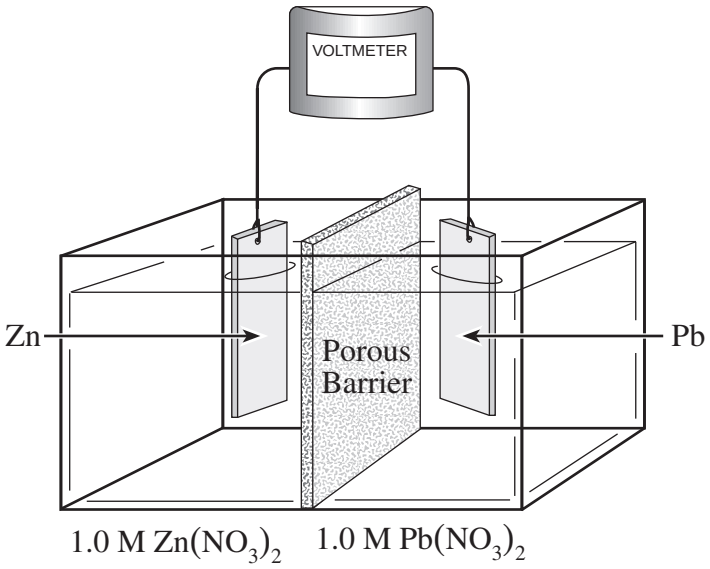
55. What changes in mass occur to the anode and cathode?

	Anode Mass	Cathode Mass
A.	decreases	increases
B.	decreases	no change
C.	increases	decreases
D.	increases	no change

56. What is the voltage for this cell under standard conditions?

A. −0.24 V
B. −0.56 V
C. +0.56 V
D. +2.16 V

57. Consider the following diagram:



As the cell operates, the voltage gradually changes. Which of the following is responsible for this change?

A. The $\left[Pb^{2+}\right]$ is increasing.

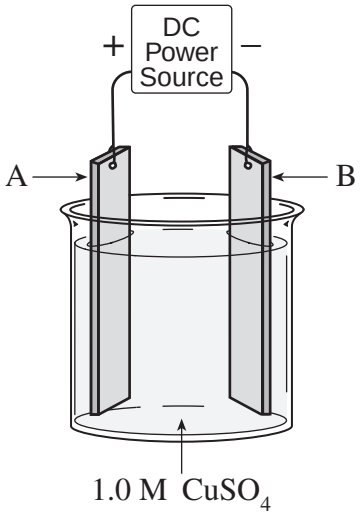
B. The $\left[Pb^{2+}\right]$ is decreasing.

C. The $\left[Zn^{2+}\right]$ is decreasing.

D. The mass of the $Pb_{(s)}$ electrode is decreasing.

OVER

Use the following diagram to answer questions 58 and 59.



58. The above cell is constructed in order to copper plate an object.
For best results, which of the following should be used for electrodes A and B?

	Electrode A	Electrode B
A.	object	pure copper
B.	pure copper	object
C.	object	any conductor
D.	any conductor	object

59. A student tries to use the above apparatus to copper plate a zinc object. What will happen if the student places the zinc object at A and the copper electrode at B?

	Electrode A	Electrode B
A.	$Cu_{(s)}$ forms	Cu dissolves
B.	Zn dissolves	$Zn_{(s)}$ forms
C.	Zn dissolves	$Cu_{(s)}$ forms
D.	Bubbles form	Bubbles form

60. Which of the following occurs during the electrolysis of molten KCl?

A. Oxygen forms at the anode.
B. Potassium forms at the anode.
C. Chlorine forms at the cathode.
D. Potassium forms at the cathode.

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

OVER

PART B: WRITTEN RESPONSE

Value: 30 marks **Suggested Time: 40 minutes**

INSTRUCTIONS: You are 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. When solid sodium is placed in water at room temperature, an immediate, violent reaction occurs:

$$2Na_{(s)} + 2H_2O_{(\ell)} \rightarrow 2NaOH_{(aq)} + H_{2(g)} + \text{energy}$$

a) Describe two methods that could be used to experimentally determine the rate of reaction. **(2 marks)**

Method 1: _____

Method 2: _____

b) Would you expect the activation energy of this reaction to be high or low? Explain, using collision theory. **(2 marks)**

_____

_____

_____

_____

2. Consider the following equilibrium:

$$N_{2(g)} + O_{2(g)} \rightleftarrows 2NO_{(g)} \qquad K_{eq} = 0.0095$$

Initially, 0.15 mol N_2 and 0.15 mol O_2 were placed in a 1.0 L container.
Calculate the concentration of all species at equilibrium. **(4 marks)**

OVER

3. a) How would a saturated solution be prepared at room temperature? **(1 mark)**

b) Write a chemical equation to illustrate the equilibrium that exists in a saturated solution of $Be_3(PO_4)_2$. **(2 marks)**

4. Using calculations, show why the electrical conductivity of $1.0\,M$ H_2CO_3 will be less than that for $0.10\,M$ HCl. **(4 marks)**

5. Water, at $60°C$, has a $K_w = 9.55 \times 10^{-14}$.

a) Write an equation representing the ionization of water. Include the heat of reaction $(57.1\,kJ)$ in the equation. **(2 marks)**

b) If a small amount of $NaOH$ is added to water, what happens to the value of K_w ? **(1 mark)**

_____

_____

OVER

6. Calculate the pH of $3.0\,M\ Na_2CO_3$. Start by writing the equation for the predominant equilibrium reaction. **(5 marks)**

7. An impure sample of CaC_2O_4 weighing $0.803\,g$ is titrated with $15.70\,mL$ of $0.101\,M$ $KMnO_4$. The net reaction is

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

What is the percent by mass of the CaC_2O_4 in the original sample? **(4 marks)**

8. A sample of Zn corrodes in moist air.

a) Write the reduction half-reaction. **(1 mark)**

b) What metal could be attached to the sample to prevent the corrosion of the zinc? Explain. **(2 marks)**

END OF EXAMINATION

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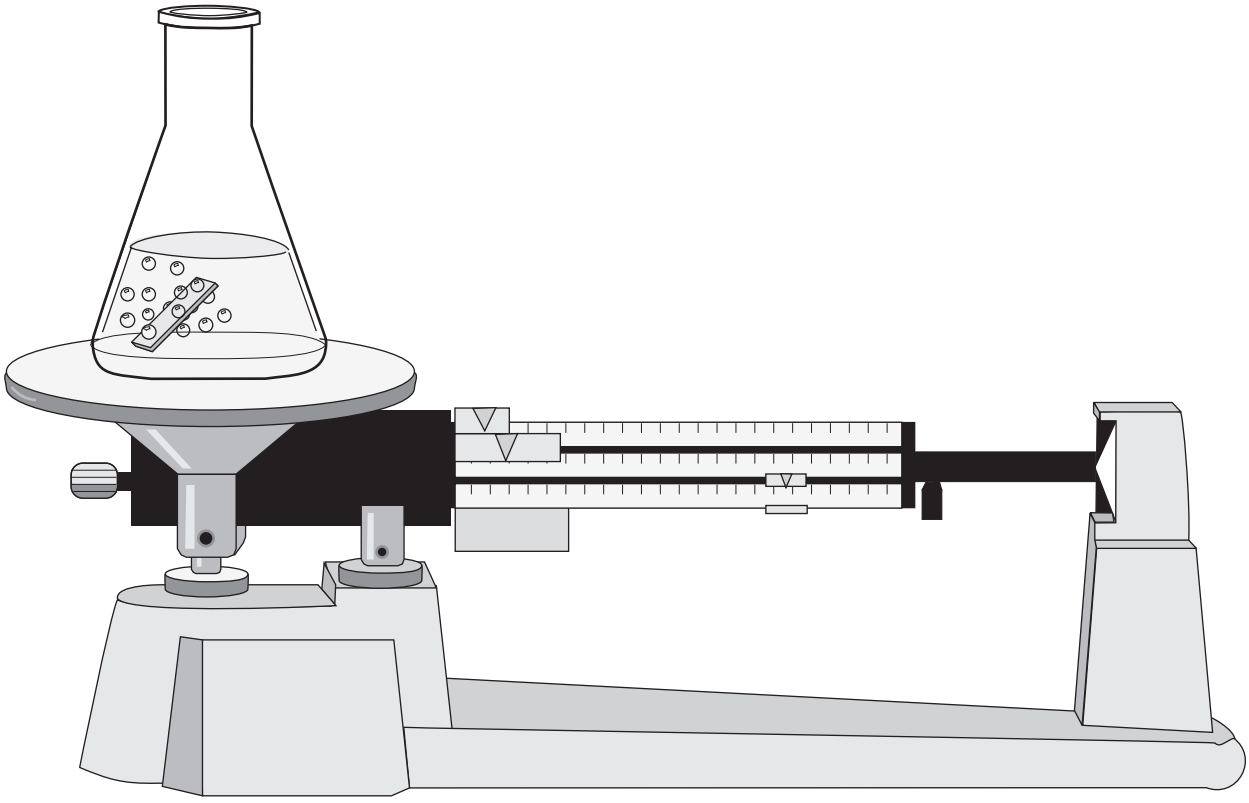
Data Booklet

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