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BRITISH COLUMBIA

Chemistry 12

APRIL 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. .

(5)

Question 7:

7. .

(4)

Question 2:

2. .

(2)

Question 8:

8. .

(4)

Question 3:

3. .

(2)

Question 9:

9. .

(3)

Question 4:

4. .

(3)

Question 10:

10. .

(3)

Question 5:

5. .

(6)

Question 11:

11. .

(4)

Question 6:

6. .

(4)

Chemistry 12

APRIL 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: 11 written-response questions	40	50
Total:	**100 marks**	**120 minutes**

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

   No other reference materials or tables are allowed.

3. **A calculator is essential for the Chemistry 12 Provincial Examination.** The calculator must be a hand-held device designed primarily for mathematical computations involving logarithmic and trigonometric functions. 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. Consider the following reaction occurring in an open container:

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

The reaction rate could be calculated by using which of the following? **(1 mark)**

A. a change in $\left[Cl^-\right]$
B. a decrease in pH value
C. a change in gas pressure
D. a decrease in the mass of the system

2. Which of the following does **not** affect both homogeneous and heterogeneous reaction rates? **(1 mark)**

A. addition of a catalyst
B. change in temperature
C. change in surface area
D. change in concentration

3. How do KE and PE change as reactant particles collide with each other? **(1 mark)**

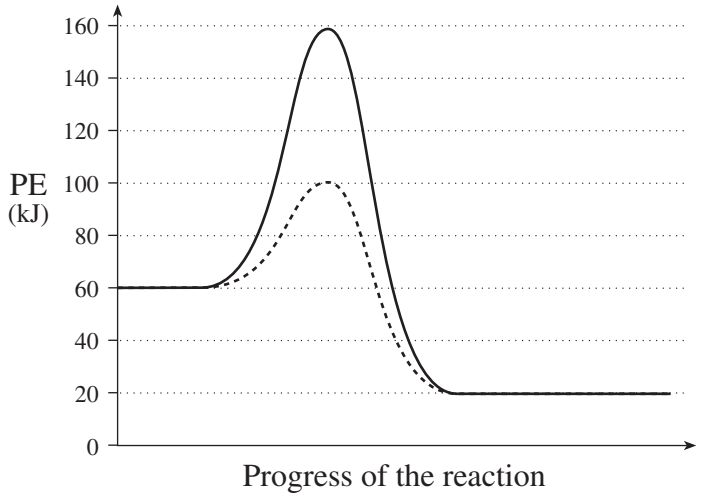
	KE	PE
A.	increases	increases
B.	increases	decreases
C.	decreases	increases
D.	decreases	decreases

OVER

4. Under which of the following conditions will the reaction rate decrease for a reaction which goes to completion? **(1 mark)**

A. A catalyst is removed.
B. Products are removed.
C. Temperature is increased.
D. Solid reactants are ground into powders.

5. Consider the following potential energy diagram for a reaction: **(2 marks)**



Which of the following represents the correct activation energies?

	Forward Catalyzed E_a	Reverse Uncatalyzed E_a
A.	40 kJ	140 kJ
B.	80 kJ	40 kJ
C.	100 kJ	80 kJ
D.	100 kJ	160 kJ

6. What is an important function of the catalyst found in an automobile exhaust system? **(1 mark)**

A. increase fuel economy
B. decrease the rate of CO_2 production
C. increase the conversion rate of NO_2 to N_2
D. increase the conversion rate of heat into work

7. For the equilibrium system below:

$$Cu_{(s)} + 2Ag^{+}_{(aq)} \rightleftarrows 2Ag_{(s)} + Cu^{+2}_{(aq)}$$

We would know the system is at equilibrium because **(1 mark)**

A. $\left[Cu^{+2}\right] = \left[Ag^{+}\right]$

B. $2\left[Cu^{+2}\right] = \left[Ag^{+}\right]$

C. the mass of $Cu_{(s)}$ remains constant.

D. the mass of the entire system remains constant.

8. For the reacting system: **(2 marks)**

$$2Li_{(s)} + 2H_2O_{(\ell)} \overset{?}{\rightarrow} 2LiOH_{(aq)} + H_{2(g)} \qquad \Delta H = -433\,kJ$$

What will entropy and enthalpy factors favour?

	Entropy	Enthalpy
A.	products	reactants
B.	products	products
C.	reactants	reactants
D.	reactants	products

OVER

9. Consider the following equilibrium:

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

If some Ne gas is added at a constant volume then how will $[N_2]$, $[H_2]$ and K_{eq} be affected? **(2 marks)**

	$[N_2]$	$[H_2]$	K_{eq}
A.	increases	increases	decreases
B.	decreases	decreases	increases
C.	decreases	increases	does not change
D.	does not change	does not change	does not change

10. What is the effect of adding a catalyst to an equilibrium system? **(1 mark)**

A. The value of E_a increases.

B. The value of K_{eq} increases.

C. Forward and reverse rates increase.

D. The concentration of products increases.

11. Consider the following equilibrium:

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

What is the K_{eq} expression? **(1 mark)**

A. $\dfrac{\left[CrO_4^{2-}\right]^2\left[H^+\right]^2}{\left[Cr_2O_7^{2-}\right]}$

B. $\dfrac{\left[Cr_2O_7^{2-}\right]}{\left[CrO_4^{2-}\right]^2\left[H^+\right]^2}$

C. $\dfrac{\left[Cr_2O_7^{2-}\right]}{\left[2CrO_4^{2-}\right]\left[2H^+\right]}$

D. $\dfrac{\left[Cr_2O_7^{2-}\right]\left[H_2O\right]}{\left[CrO_4^{2-}\right]^2\left[H^+\right]^2}$

12. A container is initially filled with pure SO_3. After a period of time, the following equilibrium is established:

$$2SO_{2(g)} + O_{2(g)} \rightleftarrows 2SO_{3(g)} \qquad K_{eq} = 7.0 \times 10^{25}$$

What does this equilibrium mixture contain? **(1 mark)**

A. mostly products

B. mostly reactants

C. $\frac{3}{5}$ reactants and $\frac{2}{5}$ products

D. equal amounts of reactants and products

13. Consider the following equilibrium:

$$2CO_{(g)} + O_{2(g)} \rightleftarrows 2CO_{2(g)} \qquad K_{eq} = 4.0 \times 10^{-10}$$

What is the value of K_{eq} for $2CO_{2(g)} \rightleftarrows 2CO_{(g)} + O_{2(g)}$? **(1 mark)**

A. 4.0×10^{-10}

B. 2.0×10^{-5}

C. 5.0×10^{4}

D. 2.5×10^{9}

14. Consider the following equilibrium:

$$H_{2(g)} + Br_{2(g)} \rightleftarrows 2HBr_{(g)} \qquad \Delta H = -36\,kJ$$

How could the value of K_{eq} be increased? **(1 mark)**

A. add H_2

B. add HBr

C. increase the pressure

D. reduce the temperature

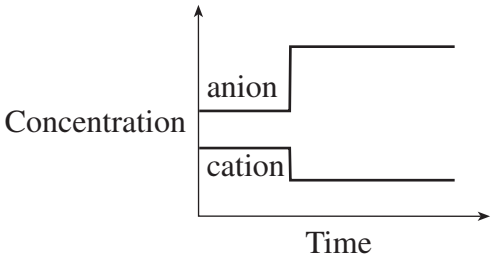
OVER

15. Which of the following is a suitable term for representing solubility? **(1 mark)**

A. grams
B. moles
C. molarity
D. millilitres per second

16. A saturated solution is prepared by dissolving a salt in water. Which of the following graphs could represent the ion concentrations as the temperature is changed? **(1 mark)**

A.



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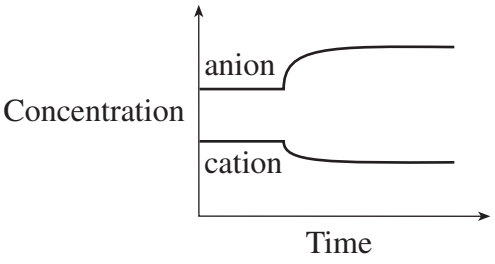

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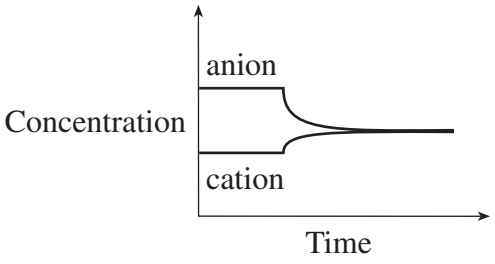
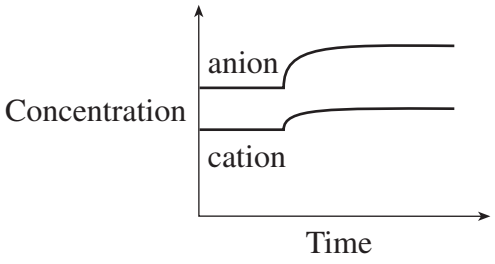


D.



17. What is the concentration of OH^- ions in 250 mL of 0.20 M $Sr(OH)_2$? **(1 mark)**

A. 0.050 M
B. 0.10 M
C. 0.20 M
D. 0.40 M

18. What happens when 10.0 mL of 0.2 M KOH is added to 10.0 mL of 0.2 M $CuSO_4$? **(1 mark)**

A. No precipitate forms.
B. A precipitate of K_2SO_4 forms.
C. A precipitate of $Cu(OH)_2$ forms.
D. Precipitates of K_2SO_4 and $Cu(OH)_2$ form.

19. Solid NaCl is added to a saturated AgCl solution. How have the $[Ag^+]$ and $[Cl^-]$ changed when equilibrium has been reestablished? **(2 marks)**

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

20. Which of the following expressions represents $[Fe^{3+}]$ in a saturated $Fe(OH)_3$ solution? **(1 mark)**

A. $\dfrac{K_{sp}}{3[OH^-]}$

B. $\dfrac{K_{sp}}{[OH^-]^3}$

C. $\sqrt[3]{\dfrac{K_{sp}}{[OH^-]}}$

D. $K_{sp} \times [OH^-]^3$

OVER

21. What is the value of K_{sp} for $Zn(OH)_2$ if the solubility of $Zn(OH)_2$ is equal to 4.2×10^{-6} M ? **(2 marks)**

A. 1.0×10^{-2}
B. 4.0×10^{-3}
C. 1.8×10^{-11}
D. 3.0×10^{-16}

22. What is the maximum number of moles of Cl^- that can exist in 500.0 mL of 2.0 M $AgNO_3$? **(1 mark)**

A. 4.5×10^{-11}
B. 9.0×10^{-11}
C. 1.8×10^{-10}
D. 1.8×10^{-9}

23. In which of the following is HSO_3^- acting as a Brønsted-Lowry acid? **(1 mark)**

A. $HSO_3^- + H_2O \rightarrow H_2SO_3 + OH^-$
B. $NH_3 + HSO_3^- \rightarrow NH_4^+ + SO_3^{2-}$
C. $HSO_3^- + HPO_4^{2-} \rightarrow H_2SO_3 + PO_4^{3-}$
D. $H_2C_2O_4 + HSO_3^- \rightarrow HC_2O_4^- + H_2SO_3$

24. What is the conjugate base of $H_2PO_4^-$? **(1 mark)**

A. OH^-
B. PO_4^{3-}
C. HPO_4^{2-}
D. H_3PO_4

25. Which of the following is correct if the four solutions listed are compared to one another? **(2 marks)**

		Concentration	Relative Conductivity	Ionization
A.	strong acid	0.50 M	highest	complete
B.	weak acid	0.50 M	lowest	complete
C.	strong base	1.0 M	highest	complete
D.	weak base	1.0 M	lowest	complete

26. Which of the following is the strongest acid that can exist in an aqueous solution? **(1 mark)**

A. O^{2-}
B. NH_2^-
C. H_3O^+
D. $HClO_4$

27. Which of the following household products could have a pH = 12.0 ? **(1 mark)**

A. soda pop
B. tap water
C. lemon juice
D. oven cleaner

28. What is the pH of a 0.050 M KOH solution? **(1 mark)**

A. 0.30
B. 1.30
C. 12.70
D. 13.70

OVER

29. What is the value of K_b for $H_2PO_4^-$? **(1 mark)**

A. 1.3×10^{-12}

B. 6.2×10^{-8}

C. 1.6×10^{-7}

D. 7.5×10^{-3}

30. Which of the following describes the net ionic reaction for the hydrolysis of $NH_4Cl_{(s)}$? **(1 mark)**

A. $NH_4^+{}_{(aq)} + Cl^-{}_{(aq)} \rightleftarrows NH_4Cl_{(s)}$

B. $NH_4Cl_{(s)} \rightleftarrows NH_4^+{}_{(aq)} + Cl^-{}_{(aq)}$

C. $Cl^-{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows HCl_{(aq)} + OH^-{}_{(aq)}$

D. $NH_4^+{}_{(aq)} + H_2O_{(\ell)} \rightleftarrows NH_{3(aq)} + H_3O^+{}_{(aq)}$

31. Which of the following salts will produce a solution with the highest pH? **(2 marks)**

A. 1.0 M $NaNO_3$

B. 1.0 M $NaHSO_4$

C. 1.0 M $NaHCO_3$

D. 1.0 M NaH_2PO_4

32. What is true about the transition point of all indicators described by the following equilibrium:

$$HIn + H_2O \rightleftarrows H_3O^+ + In^-$$

(1 mark)

A. $pH = K_a$

B. $[HIn] = [In^-]$

C. $[H_3O^+] = 1.0 \times 10^{-7}$ M

D. moles of H_3O^+ equals moles of OH^-

33. A chemical indicator has a $K_a = 4.0 \times 10^{-6}$. What is the pH at the transition point and the identity of the indicator? **(2 marks)**

	pH	Indicator
A.	5.4	methyl red
B.	5.4	bromcresol green
C.	8.6	phenolphthalein
D.	8.6	thymol blue

34. A 20.0 mL sample of HCl is titrated with 25.0 mL of 0.20 M $Sr(OH)_2$. What is the concentration of the acid? **(2 marks)**

A. 0.13 M
B. 0.20 M
C. 0.25 M
D. 0.50 M

35. Which of the following is the net ionic equation for the neutralization of $HNO_{3(aq)}$ with $Sr(OH)_{2(aq)}$? **(1 mark)**

A. $H^+_{(aq)} + OH^-_{(aq)} \rightarrow H_2O_{(\ell)}$

B. $Sr^{2+}_{(aq)} + 2NO_3{}^-_{(aq)} \rightarrow Sr(NO_3)_{2(s)}$

C. $2HNO_{3(aq)} + Sr(OH)_{2(aq)} \rightarrow Sr(NO_3)_{2(aq)} + 2H_2O_{(\ell)}$

D. $2H^+_{(aq)} + 2NO_3{}^-_{(aq)} + Sr^{2+}_{(aq)} + 2OH^-_{(aq)} \rightarrow Sr^{2+}_{(aq)} + 2NO_3{}^-_{(aq)} + 2H_2O_{(\ell)}$

36. When a strong acid is titrated with a strong base, what will the pH value be at the equivalence point? **(1 mark)**

A. 0.0
B. 6.8
C. 7.0
D. 8.6

OVER

37. Which of the following acids could **not** be present in a buffer solution? **(1 mark)**

A. HF
B. HNO_2
C. H_2SO_3
D. $HClO_4$

38. The equation for the decomposition of nitrous acid is

$$3HNO_2 \rightarrow 2NO + HNO_3 + H_2O$$

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

A. This is a redox reaction.
B. This is an acid-base reaction.
C. This is a reduction half equation.
D. This is an oxidation half equation.

39. An equation for the rusting of iron is shown below:

$$4Fe + 3O_2 \rightarrow 2Fe_2O_3$$

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

A. This is a redox reaction.
B. O_2 is the oxidizing agent.
C. Metallic iron is reduced to Fe^{3+} .
D. Metallic iron is the reducing agent.

40. In which of the following chemical changes will there be an oxidation number change of +3 ? **(1 mark)**

A. $Cr^{3+} \rightarrow Cr^{2+}$
B. $ClO^- \rightarrow ClO_2^-$
C. $Cr^{3+} \rightarrow Cr_2O_7^{2-}$
D. $Mn^{2+} \rightarrow MnO_4^-$

41. Which of the following ions can be reduced by $Pb_{(s)}$ under standard conditions? **(1 mark)**

A. Cu^{+}
B. Cr^{3+}
C. Sn^{2+}
D. Ca^{2+}

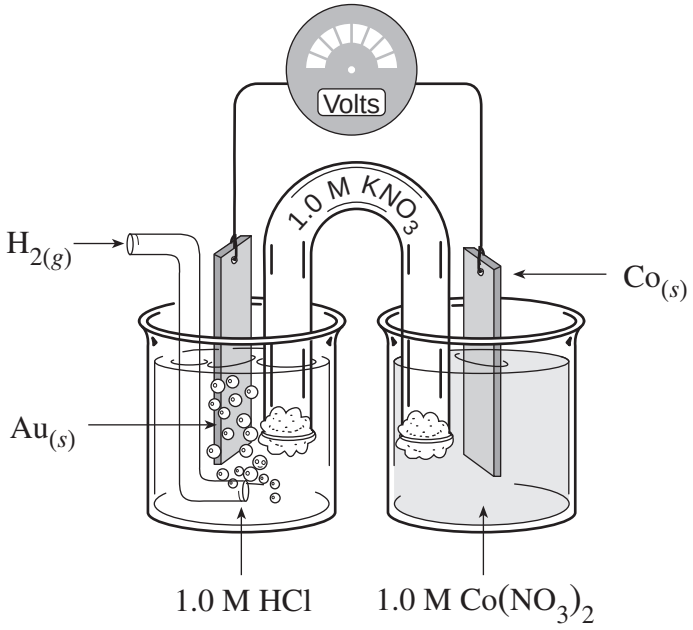
42. Consider the following equation for the combustion of ethane:

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

The change in oxidation number for carbon is equivalent to **(1 mark)**

A. 1 electron lost.
B. 7 electrons lost.
C. 1 electron gained.
D. 7 electrons gained.

43. Consider the diagram below:



Identify the cathode half reaction. **(2 marks)**

A. $H_2 \rightarrow 2H^{+} + 2e^{-}$
B. $2H^{+} + 2e^{-} \rightarrow H_2$
C. $Au^{3+} + 3e^{-} \rightarrow Au$
D. $Co^{2+} + 2e^{-} \rightarrow Co$

OVER

44. As a standard Zn / Ag electrochemical cell operates, in which direction do anions move and how does the mass of the cathode change? **(2 marks)**

	Anion Direction	Mass of Cathode
A.	towards Zn electrode	increases
B.	towards Ag electrode	increases
C.	towards Zn electrode	decreases
D.	towards Ag electrode	decreases

45. What is the standard cell potential for the following reaction: **(1 mark)**

$$2Cr_{(s)} + 3Cu^{2+} \rightarrow 2Cr^{3+} + 3Cu_{(s)}$$

A. −1.08 V
B. +0.40 V
C. +1.08 V
D. +2.50 V

46. Consider the following:

$$2Cr^{2+} + Tl^{3+} \rightarrow 2Cr^{3+} + Tl^{+} \qquad E° = +1.19\,V$$

Identify the standard potential for the half-cell reaction:

$$Tl^{+} \rightarrow Tl^{3+} + 2e^{-}$$ **(1 mark)**

A. −0.78 V
B. +1.60 V
C. +0.78 V
D. +1.19 V

47. The electrolysis of aqueous Rb_2SO_4 solution using carbon electrodes produces changes in the solution around the electrodes. How will the pH change around the anode and the cathode? **(2 marks)**

	pH around the Anode	pH around the Cathode
A.	increase	increase
B.	decrease	decrease
C.	increase	decrease
D.	decrease	increase

48. The same amount of electricity (same number of moles of electrons) is used to carry out the electrolysis of $PdCl_{2(aq)}$ and $AgNO_{3(aq)}$ solutions in separate cells. The masses of Pd and Ag produced were measured and compared. Which of the following is true about the mass of Pd produced? **(1 mark)**

A. The mass of Pd produced is not related to the mass of Ag.
B. The mass of Pd produced is approximately half that of Ag.
C. The mass of Pd produced is approximately twice that of Ag.
D. The mass of Pd produced is approximately the same as that of Ag.

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.

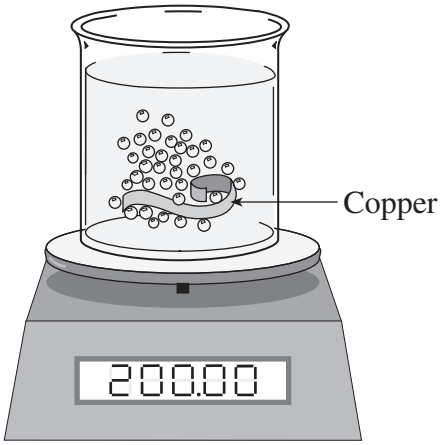
For questions involving calculations, full marks will NOT be given for providing only an answer.

1. Consider the following reaction:

$$3Cu_{(s)} + 8HNO_{3(aq)} \rightarrow 3Cu(NO_3)_{2(aq)} + 2NO_{(g)} + 4H_2O_{(\ell)}$$

A piece of copper is added to a nitric acid solution in an open beaker, allowing the $NO_{(g)}$ to escape. The following data was obtained:

TIME (min)	MASS OF BEAKER AND CONTENTS (g)
0.0	200.00
1.0	197.50
2.0	195.45
3.0	193.55
4.0	191.70
5.0	189.90
6.0	188.15
7.0	186.45
8.0	184.80



a) Calculate the reaction rate for the time period 2.0 to 6.0 min. **(2 marks)**

b) Calculate the mass of copper consumed in the first 5 minutes. **(3 marks)**

OVER

2. Using collision theory, explain why reactions between two solutions occur more rapidly than reactions between two solids. **(2 marks)**

3. Consider the following reaction for the Haber Process for ammonia production:

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

The system is normally maintained at a temperature of approximately 500°C.

a) Explain why 1000°C is not used. **(1 mark)**

b) Explain why 100°C is not used. **(1 mark)**

4. Consider the following equilibrium:

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

In an experiment, 0.100 moles of SO_3 and 0.100 moles of NO are placed in a 1.00 L container. When equilibrium is achieved, $[NO_2] = 0.0414$ mol/L. Calculate the K_{eq} value. **(3 marks)**

OVER

5. a) Write the net ionic equation for the reaction between $Pb(NO_3)_{2(aq)}$ and $NaCl_{(aq)}$.

(2 marks)

b) Determine, with calculations, whether a precipitate will form when 15.0 mL of 0.050 M $Pb(NO_3)_2$ is added to 35.0 mL of 0.085 M NaCl. **(4 marks)**

6. An acid-base reaction occurs between HSO_3^- and IO_3^- .

a) Write the equation for the equilibrium that results. **(1 mark)**

b) Identify one conjugate acid-base pair in the reaction. **(1 mark)**

c) State whether reactants or products are favoured, and explain how you arrived at your answer. **(2 marks)**

_____

_____

OVER

7. At 10°C, $K_w = 2.95 \times 10^{-15}$.

a) Determine the pH of water at 10°C. **(3 marks)**

b) State whether water at this temperature is acidic, basic or neutral, and explain. **(1 mark)**

_____

_____

8. Calculate the pH of 0.50 M H_2S. **(4 marks)**

OVER

9. Consider the following experimental results:

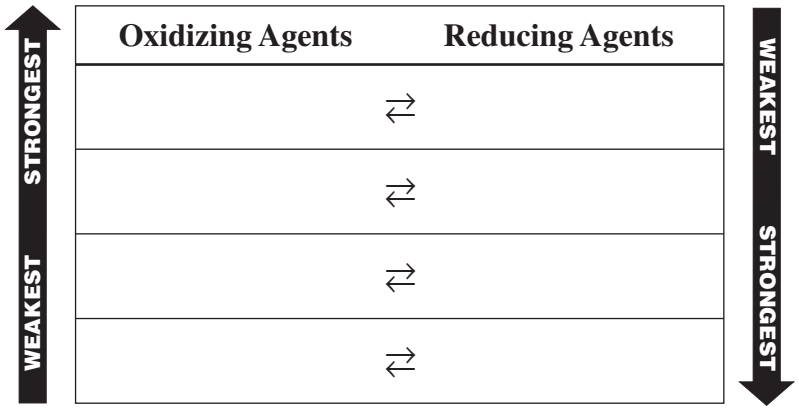
$$Ce^{4+} + Pd \rightarrow Pd^{2+} + Ce^{3+}$$

$$In^{3+} + Cd \rightarrow \text{no reaction}$$

$$Pd^{2+} + In^{2+} \rightarrow In^{3+} + Pd$$

$$Cd^{2+} + Pd \rightarrow \text{no reaction}$$

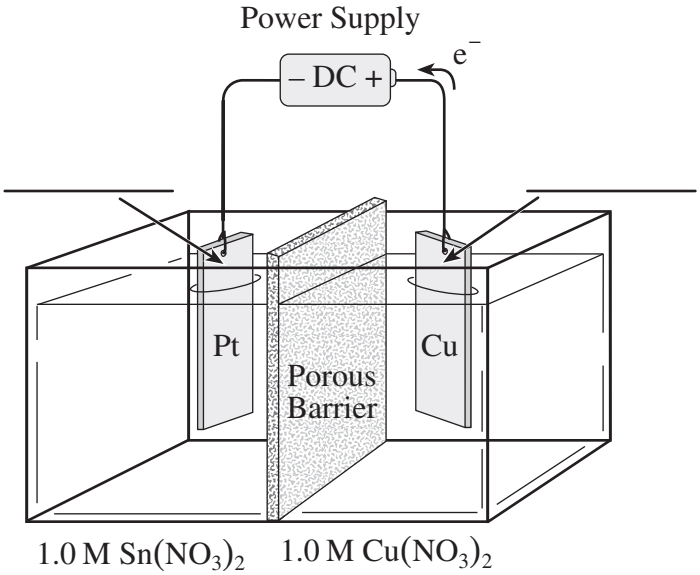
Use these results to complete the table of reduction half-reactions below. **(3 marks)**



10. Balance the following equation. **(3 marks)**

$$Cr_2O_7^{2-} + C_2O_4^{2-} \rightarrow Cr^{3+} + CO_2 \qquad \text{(acidic)}$$

11. Consider the following **electrolytic cell** which contains a porous barrier to prevent general mixing of solutions.



a) Label the anode and cathode in the space provided on the diagram above. **(1 mark)**

b) Write an equation for the overall cell reaction. **(2 marks)**

c) Calculate the minimum theoretical voltage required for this reaction under standard conditions. **(1 mark)**

END OF EXAMINATION

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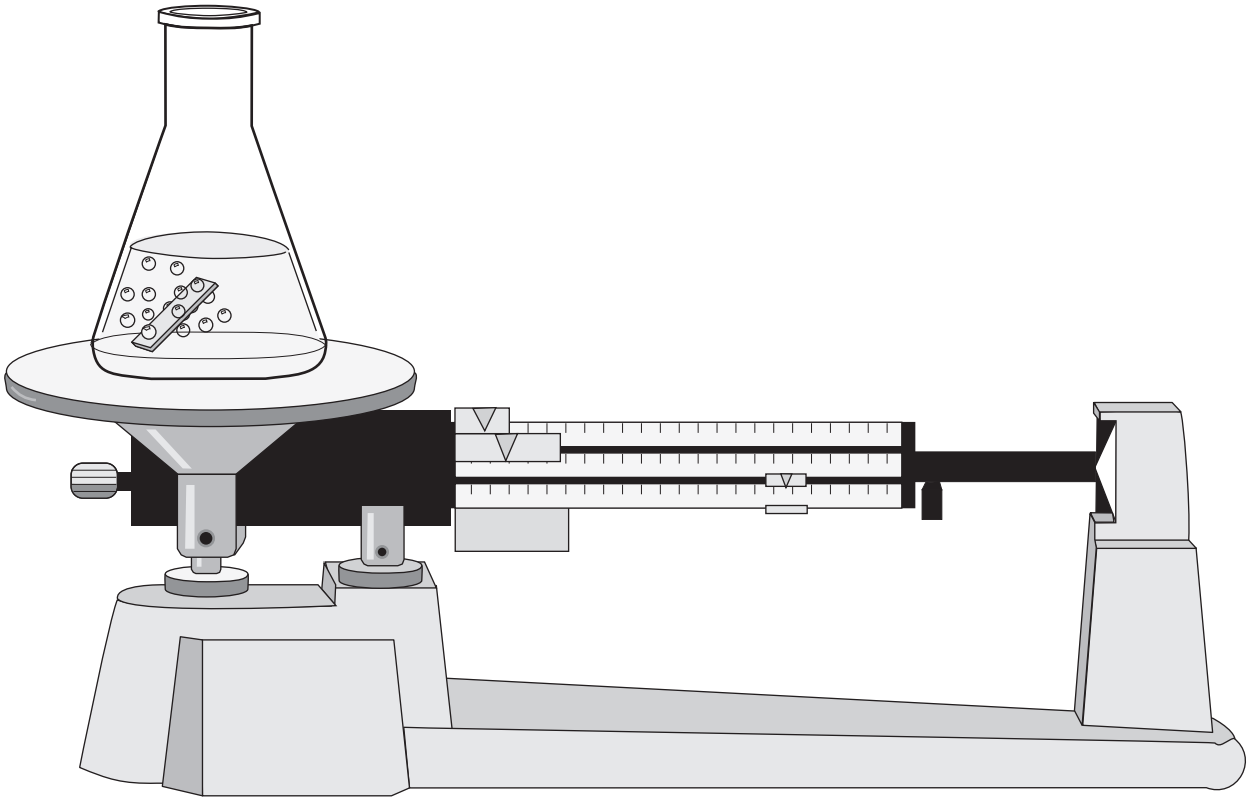
Data Booklet

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