UNIVERSITÉ Concordia UNIVERSITY

Course: CHEMISTRY	**Number:** 205/4	**Section:** 03, 04 and 52	
Instructors: P.H. Bird, G. Dénès			
Examination: Final	**Date:** 28th April, 2010	**Time:** 19:00 - 22:00	**# of pages:** 15
Materials Allowed: A data sheet and periodic table are attached to this paper - *no other materials are allowed*. **Calculators Allowed:** Yes (Cell phones or electronic dictionaries may NOT be used as calculators.)			
Special Instructions: This exam contains three sections. ***Please read the instructions before each section carefully.***			

LAST NAME: _____ FIRST NAME: _____

STUDENT NUMBER: _____ SIGNATURE: _____

PLEASE READ THIS PAGE WHILE YOU WAIT TO START.

- ***Check that you have 15 pages including this page. Please write your ID # on all pages.***
- ***A periodic table and "useful information" is provided; you CAN remove the periodic table.***
- ***Non-programmable calculators are allowed; cell phones & electronic dictionaries are not.***
- ***Read ALL questions carefully BEFORE starting the exam, and answer ALL questions.***
- ***Write all answers in the space provided. There is space on pages 13 and 14 for rough work.***
- ***YOU MUST SHOW YOUR WORK FOR ALL CALCULATIONS, except for multiple choice questions, or you will NOT get full marks.***

PLEASE RAISE YOUR HAND IF YOU NEED CLARIFICATION.

Please leave blank

Section I. The following 22 questions are multiple choice. They are worth 2 marks each. You may do rough work on your exam paper, but it will not be marked. You *must* mark your answers *using a soft pencil* on the machine readable answer form provided, *and* circle them on this exam paper. *Do not forget to mark your name and student number (your birth date is not required).*

1. A lump of magnesium metal weighing 11.81 g is dropped into a graduated cylinder containing 21.3 mL of water. The level of water in the cylinder rises to 28.1 mL. What is the density of magnesium?

   a. 0.58 g cm^{-3}
   b. 0.58 cm g^{3}
   c. 1.7 g cm^{-3}
   d. 1.74 g cm^{-3}
   e. 1.7 cm g^{-3}

   Volume of water displaced by the magnesium = 28.1 – 21.3 = 6.8 mL
   Density = mass/volume = 11.81/6.8 = 1.7 g cm^{-3}
   Note: Due to the subtraction, only 2 significant figures are retained for the volume. Therefore the density should also be reported to 2 significant figures.

2. Which *one* of the following statements is *correct*:

   a. Pure substances may be separated by filtration or distillation into at least two components.
   b. A heterogeneous mixture is also known as a solution.
   c. A heterogeneous mixture is composed of two or more substances in the same phase.
   d. The composition is uniform throughout a homogeneous mixture.
   e. A combination of two or more liquids always results in a homogeneous mixture.

3. Based on their position in the periodic table, which of these pairs of elements would you expect *both* to be malleable and good electrical conductors?

   a. phosphorus and rubidium
   b. copper and lead
   c. iodine and selenium
   d. calcium and boron
   e. sulphur and germanium

4. Consider the following description of the element, sulphur:

   1. Sulphur is a yellow non-metallic element.
   2. It burns in oxygen to form a choking gas, SO_2.
   3. SO_2 reacts with water to produce acid rain.
   4. Sulphur is produced commercially by injecting steam into deposits of it underground to melt it.
   5. It is then carried by the steam to the surface, where it separates from the water after cooling.

   Which of the above statements refer to chemical reactions, and which to physical properties or changes?

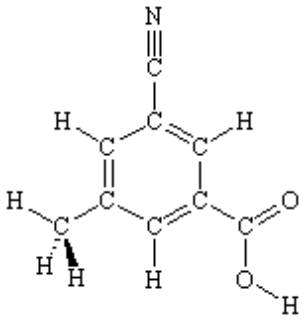
	Chemical	**Physical**
a.	Statements 2, 3, 4, and 5	Statements 1 only
b.	Statements 2 and 3	Statements 1, 4 and 5
c.	Statements 2, 3 and 4	Statements 1 and 5
d.	Statements 2, 3 and 5	Statements 1 and 4
e.	Statements 1, 4 and 5	Statements 2 and 3

5. Blue crystals of copper(II) sulphate have the formula: $CuSO_4 \cdot 5H_2O$. What is the percentage by mass of water in this substance?

   a. 63.90%
   b. 56.42%
   c. 1.772%
   d. 2.772%
   e. 36.10%

   Molecular mass of $CuSO_4 \cdot 5H_2O$:
   $63.55 + 32.07 + 4 \times 16.00 + 5 \times (16.00 + 2 \times 1.008) = 249.7$ u (or g mol^{-1})
   Molecular mass of water:
   $5 \times (16.00 + 2 \times 1.008) = 90.08$ u (or g mol^{-1})
   $\therefore$ % water = $(90.08/249.7) \times 100 = 36.1\%$

6. How many sigma (σ) bonds and pi (π) bonds are in the molecule below?



   a. thirteen σ and four π
   b. thirteen σ and six π
   c. nineteen σ and one π
   d. nineteen σ and six π
   e. six σ and nineteen π

7. Consider the oxidation – reduction reaction shown below and pick the correct statement:

   $BrO_3^-(aq) + 2MnO_2(s) + H_2O(\ell) \rightarrow Br^-(aq) + 2MnO_4^-(aq) + 2H^+(aq)$

   a. Bromine is oxidized and hydrogen is reduced.
   b. Bromine is reduced and hydrogen is oxidized.
   c. Bromine is reduced and manganese is oxidized
   d. The reaction is an acid – base reaction, NOT an oxidation – reduction reaction!
   e. Manganese is oxidized and hydrogen is reduced.

8. A red laser pointer emits light at a wavelength of 652 nm. If the laser emits 9.0×10^{-4} J of energy per second in the form of visible radiation, how many photons per second are emitted?

   a. 3.4×10^{-6} photons/sec
   b. 4.1×10^{11} photons/sec
   c. 8.9×10^{14} photons/sec
   d. 2.9×10^{15} photons/sec
   e. 5.1×10^{17} photons/sec

   $c = \lambda \cdot \nu$ or $c/\lambda = \nu = 2.9979 \times 108/652 \times 10^{-9} = 5.498 \times 10^{14}\ s^{-1}$
   $E = h \cdot \nu = 6.626 \times 10^{-34} \times 4.598 \times 10^{14} = 3.047 \times 10^{-19}$ J per photon
   $\therefore$ # of photons $= 9 \times 10^{-4}/3.047 \times 10^{-19} = 2.95 \times 10^{15}$ photons s^{-1}

9. The correct order of types of electromagnetic radiation from shortest to longest wavelength is:

   a. radio < microwave < infrared < visible < ultraviolet < X-ray < gamma ray
   b. gamma ray < radio < infrared < ultraviolet < visible < microwave < X-ray
   c. visible < radio < infrared < ultraviolet < microwave < X-ray < gamma ray
   d. gamma ray < X-ray < ultraviolet < visible < infrared < microwave < radio
   e. X-ray < ultraviolet < visible < infrared < microwave < radio < gamma ray

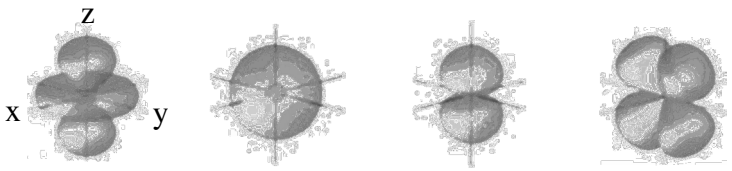
10. Which of the following cations has 4 unpaired electrons?

		Conf.	s	d				
a.	Ni^{2+}	$s^0\ d^8$		↑↓	↑↓	↑↓	↑	↑
b.	Fe^{2+}	$s^0\ d^6$		↑↓	↑	↑	↑	↑
c.	Pb^{2+}	s^2	↑↓					
d.	Mn^{2+}	$s^0\ d^5$		↑	↑	↑	↑	↑
e.	Cu^{2+}	$s^0\ d^9$		↑↓	↑↓	↑↓	↑↓	↑↓

11. Which combination of the quantum numbers n, ℓ, m_ℓ, and m_s can an electron in a 4d orbital take?

	n	$\boldsymbol{\ell}$	$\boldsymbol{m_\ell}$	$\mathbf{m_s}$
a.	4	3, 2, 1 or 0	3, 2, 1. 0. –1, –2 or –3	+½ or –½
b.	4	2	2, 1, 0, –1 or –2	+½ or –½
c.	> or = 0	2	0	+½ or –½
d.	> or = 4	2	2, 1, 0, –1 or –2	+½ or –½
e.	< or = 4	2, 1 or 0	2, 1. 0. –1 or –2	+½ or –½

12. The following diagrams represent atomic orbitals. (The axes are labeled as shown on orbital (i).)



(i) (ii) (iii) (iv)

Which of the following statements is INCORRECT:

a. Orbital (i) has a "donut" (toroidal) shaped region of electron density .
b. Diagram (ii) represents the 2s orbital.
c. Orbital (iii) represents the $2p_x$ orbital.
d. Orbital (iv) has nodes in the xz and xy planes.
e. Diagrams (i) and (iv) represent 3d orbitals.

13. In the Bohr model of the hydrogen atom, the electron was assumed to travel in circular (or elliptical) orbits. Which of the following statements is INCORRECT?

a. Bohr theory cannot handle systems with more than one electron.
b. Bohr theory treats the electron as a particle.
c. Bohr theory predicts the wavelengths of the lines in the emission spectrum of hydrogen.
d. Bohr theory successfully explains the existence of molecular hydrogen, H_2.
e. Bohr theory states that only certain orbital radii are possible.

14. Which 2+ ion has the ground state electronic configuration [Xe] $5d^{10}\ 4f^{14}\ 6s^2$?

a. Barium
b. Mercury(I)
c. Mercury(II)
d. Lead(II) – Plumbous (See also Q10)
e. Lead(IV) – Plumbic

15. Place the following atoms in order from smallest to largest (first) ionization energy: Al , Si, P, S and Cl.

    a. Al < Si < P < S < Cl
    b. Cl < S < P < Si < Al
    c. Al < Si < P < Cl < S
    d. Al < P < Si < S < Cl
    e. Al < Si < S < P < Cl This answer shows the reversal of P and S due to electron pairing.

16. Place the ion pairs NaF, KF and MgO in order of *increasing* coulombic attraction.

    a. NaF < KF < MgO
    b. MgO < KF < NaF
    c. KF < NaF < MgO
    d. KF = NaF < MgO
    e. MgO < KF = NaF

17. An aqueous sodium hydroxide solution has a pH of 12.43. What concentration of H^+ is present in 250. mL of this solution?

    a. 1.6×10^{-12} M
    b. 2.5×10^{12} M
    c. 1.0×10^{-13} M
    d. 9.3×10^{-14} M
    e. 3.7×10^{-13} M Molarity = $10^{-pH} = 10^{-12.43} = 3.7 \times 10^{-13}$ M

18. An example of a non-electrolyte in water is:

    a. NH_4NO_3
    b. HCl
    c. NaOH
    d. K_2SO_4
    e. Br_2

19. An example of a weak acid in water is:

    a. HNO_3
    b. HBr
    c. NH_3
    d. H_2SO_4
    e. CH_3COOH

20. Which of the following statements concerning real gases is or are CORRECT?

    1. Real gases are always liquids or solids at temperatures below 273.15 K.
    2. The pressure of a real gas is higher than predicted by the ideal gas law.
    3. The molecules in a real gas are attracted to each other.

    a. 1 only
    b. 2 only
    c. 3 only
    d. 2 and 3
    e. 1, 2 and 3

21. Which of the following statements is or are CORRECT?

    1. All ionic compounds that are soluble in water are electrolytes.
    2. All ionic compounds dissolve in water.
    3. Molecular compounds are never soluble in water.

    a. 1 only
    b. 2 only
    c. 3 only
    d. 2 and 3
    e. 1 and 3

22. How long will it take 10.0 mL of H_2 gas to effuse through a porous barrier if it has been observed that 166 minutes are required for 10.0 mL of CH_4 gas to effuse through the same barrier?

    a. 2.62 min
    b. 20.9 min
    c. 58.9 min
    d. 468 min
    e. 1.05×10^4 min

    Graham's Law: $\frac{\text{rate(B)}}{\text{rate(A)}} = \frac{\text{time(A)}}{\text{time(B)}} = \sqrt{\frac{mm(A)}{mm(B)}}$ $\quad \frac{x}{166.} = \sqrt{\frac{mm(H_2)}{mm(CH_4)}} = \sqrt{\frac{2.026}{16.042}}$

    $\therefore$ Effusion time for H_2 = 58.9 min

Section II. The following 7 questions require short answers and should be answered in the space provided on this paper. Do not forget to provide a brief explanation where it is requested.

23. (4 marks) Provide the missing name or formula for each substance below:

$Fe_3(PO_4)_2$	____iron(II) phosphate or ferrous phosphate____
XeF_6	____xenon hexafluoride._____
____P_4O_{10}_____	tetraphosphorus decoxide
____$Mg(NO_3)_2$_	magnesium nitrate

24. (3 marks) The diagram to the right represents the gas-phase reaction of A_2 (darker spheres) with B_2 (lighter spheres). Write a balanced equation for the reaction, and identify the limiting reactant (reagent). Explain briefly.

Balanced Equation:

$A_2(g) + 3\ B_2(g) \rightarrow 2\ AB_3(g)$

It is not appropriate to just show everything in the equation, i.e.:

$4\ A_2(g) + 6\ B_2(g) \rightarrow 4\ AB_3(g) + 2\ A_2$

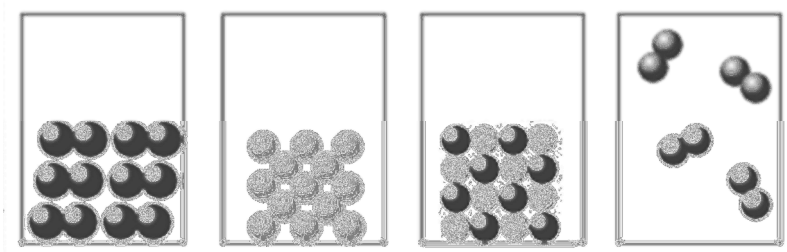
Limiting reactant:

B_2 is limiting because there is leftover A_2 after the reaction.

25. (2 marks) The pictures to the right represent samples of each of the following substances at 25°C:

sodium, chlorine, iodine, sodium chloride

Label each picture with the name and state of the substance it represents:



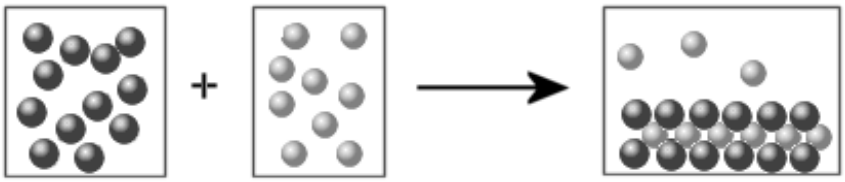
I_2 Na NaCl Cl_2

a. I_2 is a black crystalline solid
b. Na is a solid (crystalline metal)
c. NaCl is a crystalline solid.
d. Cl_2 is a green gas

26. (4 marks) Assume that an aqueous solution containing cations (dark spheres) is allowed to mix with a solution containing anions (light spheres), and that the following result is obtained (diagram). The water molecules and spectator ions are not shown.

Which combination(s) of cation and anion, chosen from the following lists, are compatible with the observed results? Explain briefly.

Cations: Na^+, Ca^{2+}, Ag^+, Ni^{2+}
Anions : Cl^-, CO_3^{2-}, CrO_4^{2-}, NO_3^-

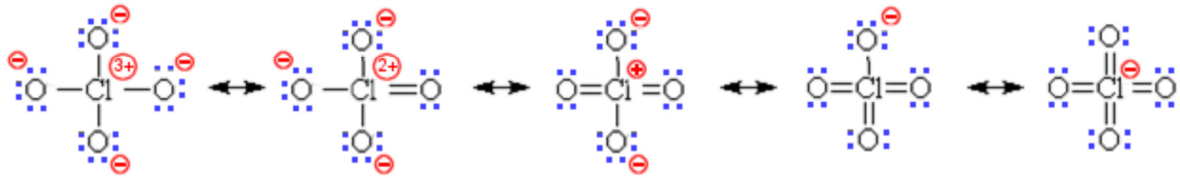


The right-hand diagram, shows that the reaction produces an insoluble crystalline compound with cation:anion stoichiometry 2:1. This means an insoluble combination of a 1+ cation with a 2– anion:

Na_2CO_3 or Na_2CrO_4 or Ag_2CO_3 or Ag_2CrO_4

Both the silver salts would be insoluble, therefore the cation is Ag^+ and the anion either CO_3^{2-} or CrO_4^{2-}.

27. (2 marks each part) The diagrams below show a series of *non-equivalent* resonance (canonical) structures for the perchlorate ion, ClO_4^-. Supply the requested information.



a. On each diagram, *clearly* mark in the lone pairs on the oxygen atoms as appropriate.

b. In each space below, say how many *equivalent* resonance structures there are for each structure directly above the space, *including the one shown*.

1	4	6	4	1

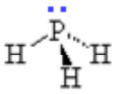
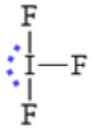
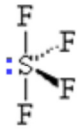
c. In each space below, specify the average Cl – O bond order for the set of equivalent structures in part a.

1	1.25	1.5	1.75	2

d. In each space below specify the average charge on oxygen for the set of equivalent structures in part a.

–1	–0.75	–0.5	–0.25	0

28. (2 marks each part) For each of the molecules depicted below, supply the requested information.

				
a. On each diagram, mark the lone pairs on the central atom. Assume each species is neutral (not an ion).				
b. In each space below, specify the basic "electron-pair" geometry of the molecule above it.				
Tetrahedral	Trigonal bipyramid	Trigonal bipyramid	Octahedral	Trigonal bipyramid
c. In each space below, specify the molecular geometry of the molecule above it.				
Trigonal pyramid	T-Shaped	See-saw	Square pyramid	Linear
d. In each space below, specify the appropriate hybridization of the atomic orbitals of the central atom.				
sp^3	sp^3d	sp^3d	sp^3d^2	sp^3d
e. In each space below, indicate whether the molecule above it is polar or non-polar.				
Polar	Polar	Polar	Polar	Non-polar

29. (2 marks each part) Consider the molecule SF_4 in question 28:

a. What are the formal charges on sulphur and fluorine?

Zero (both)

b. What are the oxidation numbers of sulphur and fluorine?

S +4 F –1

c. How are the S – F bonds polarized: $S^{(\delta+)} - F^{(\delta-)}$ or $S^{(\delta-)} - F^{(\delta+)}$? (Explain in one sentence.)

$S^{(\delta+)} - F^{(\delta-)}$ because F is more electronegative than S

d. Is the entire molecule polar? (Explain in one sentence.)

Yes: The direction dipole will lie between the 2 equatorial F's since their individual bond dipoles do not cancel out, while the bond dipoles of the axial ones do.

e. The experimentally observed molecular geometry of SF_4 is shown in the diagram, but there is another possibility consistent with the Lewis structure and basic geometry which is not observed. What is it, and why is it not observed?

The lone pair might be placed in an axial position but this would result in three 90° angles between the lone pair and the bond pairs. Placing the lone pair equatorial reduces the 90° angles to two.

Section III. Answer the following 3 questions with *complete* written answers on this exam paper. If you need more space, use the blank space provided on pages 13 and 14. *Be sure to provide adequate explanations or details to justify your answers*

30. (a) (5 marks) If 5.00 g Br_2 and 3.00 g NH_3 react according to the equation below, what is the maximum mass of ammonium bromide that could be produced?

$$3\ Br_2(\ell) + 8\ NH_3(g) \rightarrow 6\ NH_4Br(s) + N_2(g)$$

Starting quantities:

Molar masses:	159.8	17.034	97.942 g mol^{-1}
Moles available:	5.00/159.8 = 0.03129	3.00/17.034 = 0.1761mol	

Determine limiting reactant:

Mole ratio Br_2:NH_3: 0.03129/0.1761 = 0.1777

Required mole ratio: = 3/8 = 0.375

0.1777< 0.375 ∴ NH_3 is in excess and Br_2 is limiting

Determine moles NH_4Br produced: (0.3129 x 6/3) = 0.06258 mol

Calculate mass of NH_4Br produced: 0.06258 x 97.842 = 6.13 g

(b) (1 mark) If 4.71 g of ammonium bromide is isolated from the reaction, what is the percentage yield?

% yield = (actual yield/theoretical yield) x 100 = 4.71/6.13 = 76.8 %

31. (5 marks) Water can be decomposed by electrolysis into hydrogen gas and oxygen gas. What mass of water must decompose to fill a 5.00 L pressure resistant cylinder to a total pressure of 2.50 atm at 298 K with a mixture hydrogen and oxygen? (By the way, this could be a pretty stupid thing to do – suggest why.)

$$2\ H_2O(\ell) \rightarrow 2\ H_2(g) + O_2(g)$$

Calculate total pressure of $H_2 + O_2$ using PV = nRT
where P = pressure (2.50 atm), V = volume (5.00 L), n = number of moles (?) T = Temperature (298 K),
R = the gas constant. (0.08206 $L \cdot atm \cdot mol^{-1}K^{-1}$)

Rearrange the Ideal Gas Law and calculate the total number of moles:
n = (P x V)/(R x T) = (2.50 x 5.00)/(0.08026 x 298.15 = 0.511

Number of moles of H_2 = (2/3) x 0.511 = 0.3406 mol (By Daltons law of partial pressures.)
(Number of moles of O_2 = (1/3) x 0.511 = 0.1703 mol)

1 mole of H_2O decomposes to yield 1 mole of H_2
$\therefore$ Moles of H_2O = 0.2406
Mass H_2O = 0.3406 x (15.999 + 2 x 1.008) = 6.14 g

The mixture of H_2 and O_2 is explosive so don't try this at home!

32. Chlorine gas was first prepared in 1774 by C. W. Scheele by the reaction of sodium chloride with manganese(IV) oxide in aqueous sulfuric acid, according to the reaction described by the following ***unbalanced*** equation:

$$NaCl(aq) + H_2SO_4(aq) + MnO_2(s) \rightarrow Na_2SO_4(aq) + MnSO_4(aq) + H_2O(\ell) + Cl_2(g)$$

a. (1 mark) Write the unbalanced ***complete ionic*** equation.

$$Na^+(aq) + Cl^-(g) + MnO_2(s) \rightarrow Na^+(aq) + Mn^{2+}(aq) + Cl_2(g)$$

(Or* $Na^+(aq) + Cl^-(g) + H_2SO_4(aq) + MnO_2(s) \rightarrow Na^+(aq) + Mn^{2+}(aq) + SO_4^{2-} + Cl_2(g) + H_2O(\ell)$)

b. (1 mark) Write the unbalanced ***net ionic*** equation

$$Cl^-(g) + MnO_2(s) \rightarrow Mn^{2+}(aq) + Cl_2(g)$$

(Or* $Cl^-(g) + MnO_2(s) + H^+(aq) \rightarrow Mn^{2+}(aq) + Cl_2(g) + H_2O(\ell)$)

* In balancing an equation like the one in this question, it would be normal to leave out the acid and the water while balancing the half reactions because the water and then the H^+ is (re)introduced as part of the process.

In addition, the H_2SO_4 could be shown ionized as $H^+(aq) + HSO_4^-(aq)$ (or less correctly as $2\ H^+(aq) + SO_4^{2-}(aq)$).

The sulphate could be put (back) in at the end to balance the charges if a ***complete*** equation was required (like the one in the question) – see below.

c. (1 mark) Give the oxidation number of one atom of all elements in each compound of reactants and products in the ***net ionic*** equation.

$$-1 \qquad +4, -2 \qquad +2 \qquad 0$$

d. (1 mark) Identify the elements that are oxidized and the elements that are reduced.

Cl is oxidized (–1 to 0) and Mn is reduced (+4 to +2)

e. (1 mark) Identify the oxidizing agents and the reducing agents.

The oxidizing agent is MnO_4^- and the reducing agent is Cl^-

f. (4 marks) Balance the ***net ionic*** equation using the half reactions method.

Separate half-reactions:	$MnO_2 \rightarrow Mn^{2+}$	$Cl^- \rightarrow Cl_2$
Balance Mn and Cl:	$MnO_2 \rightarrow Mn^{2+}$	$2\ Cl^- \rightarrow Cl_2$
Balance O_2 with H_2O:	$MnO_2 \rightarrow Mn^{2+} + 2\ H_2O$	$2\ Cl^- \rightarrow Cl_2$
Balance H with H^+:	$4\ H^+ + MnO_2 \rightarrow Mn^{2+} + 2\ H_2O$	$2\ Cl^- \rightarrow Cl_2$
Balance charges with e^-:	$2\ e^- + 4\ H^+ + MnO_2 \rightarrow Mn^{2+} + 2\ H_2O$	$2\ Cl^- \rightarrow Cl_2 + 2\ e^-$
Add (# e– already the same):	$\cancel{2\ e^-} + 4\ H^+ + MnO_2 + 2\ Cl^- \rightarrow Mn^{2+} + 2\ H_2O + Cl_2 + \cancel{2\ e^-}$	
∴ Net ionic equation:	$4\ H^+ + MnO_2 + 2\ Cl^- \rightarrow Mn^{2+} + 2\ H_2O + Cl_2$	

With the Na^+ and SO_4^{2-} included and the equation written as in the question:

$$2\ NaCl(aq) + 2\ H_2SO_4(aq) + MnO_2(s) \rightarrow Na_2SO_4(aq) + MnSO_4(aq) + 2\ H_2O(\ell) + Cl_2(g)$$

POTENTIALLY USEFUL INFORMATION

Atomic mass unit	1 amu = 1.66054×10^{-27} kg
Avogadro's number	N = 6.022×10^{23} mol^{-1}
Definition of *Joule*	1 J = 1 $kg\cdot m^2\cdot s^{-2}$
Definition of *Pascal*	1 Pa = 1 $kg\cdot m^{-1}\cdot s^{-2}$
Gas constant	R = 0.08206 $L\cdot atm\cdot mol^{-1}K^{-1}$ = 8.314 $J\cdot mol^{-1}K^{-1}$
Planck's constant	h = 6.626×10^{-34} J·s
Pressure units	760 mm Hg = 760 torr = 1 atm = 101.325 kPa = 1.01325 bar
Rydberg constant	R = 1.0974×10^7 m^{-1}
Speed of light	c = 2.9979×10^8 $m\cdot s^{-1}$
Temperature	0 K = –273.15 ^oC

Periodic Table of the Elements

1																	18
1 **H** 1.008	2											13	14	15	16	17	2 **He** 4.00
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.007	8 **O** 15.999	9 **F** 18.998	10 **Ne** 20.18
11 **Na** 22.99	12 **Mg** 24.31	3	4	5	6	7	8	9	10	11	12	13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.07	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.87	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.69	29 **Cu** 63.55	30 **Zn** 65.39	31 **Ga** 69.72	32 **Ge** 72.61	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37 **Rb** 85.47	38 **Sr** 87.62	39 **Y** 88.91	40 **Zr** 91.22	41 **Nb** 92.91	42 **Mo** 95.94	43 **Tc** (97.91)	44 **Ru** 101.07	45 **Rh** 102.91	46 **Pd** 106.42	47 **Ag** 107.87	48 **Cd** 112.41	49 **In** 114.82	50 **Sn** 118.71	51 **Sb** 121.76	52 **Te** 127.60	53 **I** 126.90	54 **Xe** 131.29
55 **Cs** 132.91	56 **Ba** 137.33	**La-Lu**	72 **Hf** 178.49	73 **Ta** 180.95	74 **W** 183.84	75 **Re** 186.21	76 **Os** 190.2	77 **Ir** 192.22	78 **Pt** 195.08	79 **Au** 196.97	80 **Hg** 200.59	81 **Tl** 204.38	82 **Pb** 207.2	83 **Bi** 208.98	84 **Po** 208.98	85 **At** 209.99	86 **Rn** 222.02
87 **Fr** 223	88 **Ra** 226.03	**Ac-Lr**	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)									

57 **La** 138.91	58 **Ce** 140.12	59 **Pr** 140.91	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.35	63 **Eu** 151.97	64 **Gd** 157.25	65 **Tb** 158.93	66 **Dy** 162.50	67 **Ho** 164.93	68 **Er** 167.26	69 **Tm** 168.93	70 **Yb** 173.04	71 **Lu** 174.97
89 **Ac** 227.03	90 **Th** 232.04	91 **Pa** 231.04	92 **U** 238.03	93 **Np** (237)	94 **Pu** (245)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (260)