Oxidation ReductionReactions

Conclusion of ch 4

Hanson Activity 4-4

- Discuss Key Questions 1-4 of Activity 4-4, page 68, with your partner for five minutes.
- The clicker quiz will commence at 8:50 AM sharp

What is the oxidation number the pure element S_8?

1. -2
2. -1
3. 0
4. +1
5. +2
6. +8

For the ion SO_4^{2-}, what is the <u>sum</u> of the oxidation numbers of S and the four O atoms?

1. +2
2. +1
3. 0
4. -1
5. -2
6. None of the above

Why does Cl have a negative oxidation number in CCl_4, but a positive oxidation number in HClO?

1. Cl is <u>more</u> electronegative than C, but <u>less</u> electronegative than O. 0%
2. Cl is <u>less</u> electronegative than C, but <u>more</u> electronegative than O. 0%
3. There are more Cl atoms in CCl_4 0%
4. HClO is an acid 0%
5. It just one of the "mysteries" of chemistry. 0%

Table 4.3

Rules for Assigning Oxidation States

1. The oxidation state of an atom in an element is 0. For example, the oxidation state of each atom in the substances Na(*s*), $O_2(g)$, $O_3(g)$, and Hg(*l*) is 0.
2. The oxidation state of a monatomic ion is the same as its charge. For example, the oxidation state of the Na^+ ion is +1.
3. In its covalent compounds with nonmetals, hydrogen is assigned an oxidation state of +1. For example, in the compounds HCl, NH_3, H_2O, and CH_4, hydrogen is assigned an oxidation state of +1.
4. Oxygen is assigned an oxidation state of −2 in its covalent compounds, such as CO, CO_2, SO_2, and SO_3. The exception to this rule occurs in peroxides (compounds containing the O_2^{2-} group), where each oxygen is assigned an oxidation state of −1. The best-known example of a peroxide is hydrogen peroxide (H_2O_2).

state of −1. The best-known example of a peroxide is hydrogen peroxide (H_2O_2).

5. In binary compounds, the element with the greater attraction for the electrons in the bond is assigned a negative oxidation state equal to its charge in its ionic compounds. For example, fluorine is always assigned an oxidation state of −1. That is, for purposes of counting electrons, fluorine is assumed to be F^-. Nitrogen is usually assigned −3. For example, in NH_3, nitrogen is assigned an oxidation state of −3; in H_2S, sulfur is assigned an oxidation state of −2; in HI, iodine is assigned an oxidation state of −1; and so on.
6. The sum of the oxidation states must be zero for an electrically neutral compound and must be equal to the overall charge for an ionic species. For example, the sum of the oxidation states for the hydrogen and oxygen atoms in water is 0; the sum of the oxidation states for the carbon and oxygen atoms in CO_3^{2-} is −2; and the sum of oxidation states for the nitrogen and hydrogen atoms in NH_4^+ is +1.

Chemical Species	Oxidation Number	Rationale
O_2	0	The oxidation number of an atom of a pure element is always 0 because there is no electronegativity difference when all the atoms are the same.
Fe metal	0	
He	0	The oxidation number of an atom or a monatomic ion is its charge.
Mg^{2+}	+2	
Cl^-	−1	
H_2O	H = +1	Hydrogen in a compound has an oxidation number of +1 unless it is combined with a metal having a smaller electronegativity, in which case it is −1.
CH_4		
LiH	H = −1	
NaH		
HF	F = −1	Fluorine in a compound always has an oxidation number of −1 because it is the most electronegative element.
CF_4	F = −1	
H_2O	O = −2	Oxygen in a compound has an oxidation number of −2 unless it is a peroxide, in which case it is −1, or is combined with fluorine.
H_2O_2	O = −1	
Na_2O_2		
OF_2	+2(O) − 1(F) • 2 = 0	In a polyatomic molecule or ion, the sum of all the oxidation numbers of the atoms is equal to the charge on the molecule or ion.
BrCl	Cl = −1 Br = +1	If the above rules do not determine all the oxidation numbers, the most electronegative atom is assigned an oxidation number equal to the charge it would have if it had 8 valence electrons.

Activity 04.4 Electron Transfer Reactions

Exercise 1, page 69, using Model 1

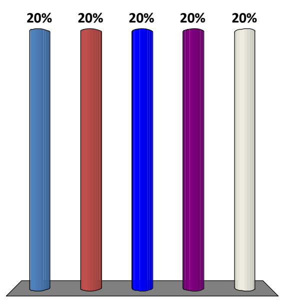
- At the projector: O_2, H_2O, CH_4, CO_2, and SF_6
- With your partner complete Ex 1

In SO_4^{2-}, the oxidation number of S is:

1. +2
2. +4
3. +6
4. -2
5. -4

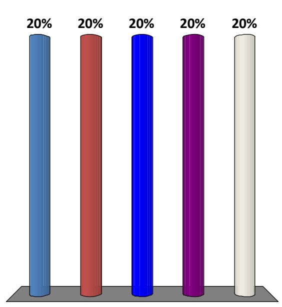
In H_2S, the oxidation number of S is:

1. +2
2. +4
3. +6
4. -2
5. -4



In Na_2SO_3, the oxidation number of S is:

1. +2
2. +4
3. +6
4. -2
5. -4



Model 2, p. 70 Key Questions

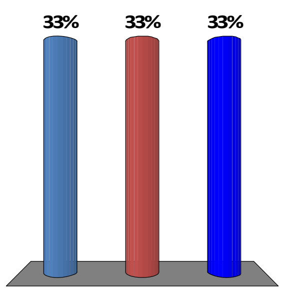
$2\ Cu(s) + O_2(g) \rightarrow 2\ CuO(s)$

5. How many electrons are transferred from one copper atom to one oxygen atom?
6. What are the oxidation numbers in all three species?

$2\ Cu(s) + O_2(g) \rightarrow 2\ CuO(s)$

Which species is oxidized?

1. CuO(s)
2. Cu(s)
3. $O_2(g)$



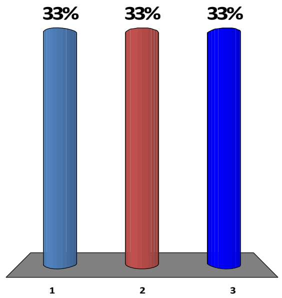
Model 2, p. 70 Key Questions

$2\ Cu(s) + O_2(g) \rightarrow 2\ CuO(s)$

7. Which species is reduced?
8. What is the oxidizing agent? The reducing agent?

If the oxidation number of a species increases during a reaction, that species acts as:

1. A reducing agent
2. An oxidizing agent
3. Either one, depending on the other species



Model 2, p. 70 Key Questions

$2\ Cu(s) + O_2(g) \rightarrow 2\ CuO(s)$

7. Which species is reduced?
8. What is the oxidizing agent? The reducing agent?
9. If a species has an increase in oxidation number, is it an oxidizing agent or reducing agent?
10. How can we distinguish redox reactions from the other types.

Exercise 2, page 70, at projector

$FeO(s) + CO(g) \rightarrow Fe(s) + CO_2(g)$

- Assign ox numbers
- Identify species oxidized/reduced
- Identify oxidation/rededuction agents
- Is it balanced?
- Can you tell from the number of electrons transferred?
- Do Exercises 2b-2f with partner. (2f is unbalanced)

Problem 4-69c to balance:

- $C_3H_8(g) + O_2(g) = CO_2(g) + H_2O(l)$

-8/3 +1 0 +4 -2 +1 -2

What is oxidized? How many electrons are lost per atom?

4 – (-8/3) or (20/3) per C atom

What is reduced? How many electrons are gained/atom?

2 per O atom

What is the ratio of O atoms/Catom?

\# electrons lost = # electrons gained

\#C atoms x (20/3) = #O atoms x (2)

\#O atoms = (#C atoms) (20/3)(1/2) = (10/3)(#C atoms)

Problem 4-69c to balance:

- $C_3H_8(g) + O_2(g) = CO_2(g) + H_2O(l)$

-8/3 +1 0 +4 -2 +1 -2

\#O atoms = (10/3)(#C atoms)

$C_3H_8(g) + 5\ O_2(g) = CO_2(g) + H_2O(l)$

$C_3H_8(g) + 5\ O_2(g) = 3CO_2(g) + H_2O(l)$

$C_3H_8(g) + 5\ O_2(g) = 3\ CO_2(g) + 4\ H_2O(l)$

Problem 4-69c to balance:

- $C_3H_8(g) + O_2(g) = CO_2(g) + H_2O(l)$

-8/3 +1 0 +4 -2 +1 -2

Can be done by inspection w/o oxidation numbers

$C_3H_8(g) + O_2(g) = 3\ CO_2(g) + H_2O(l$

$C_3H_8(g) + O_2(g) = 3\ CO_2(g) + 4\ H_2O(l)$

$C_3H_8(g) + 5\ O_2(g) = 3\ CO_2(g) + 4\ H_2O(l)$

Do the electrons exchanged balance?

C: 3 atoms from -8/3 to +4 = 3 x (20/3) = 20

O: 10 atoms from 0 to -2 = 10 x (2) = 20

Problem 71-a in acid soln

- $Cu(s) + NO_3^-(aq) = Cu^{2+}(aq) + NO(g)$
- 0 +5 -2 +2 +2 -2
- Each copper atom loses 2 electrons (0 -> +2)
- Each nitrogen atom gains 3 electrons (+5 -> +2)
- What must be the ration of N to Cu atoms?
- 3 Cu: 2 N
- $3\ Cu(s) + 2\ NO_3^-(aq) = 3Cu^{2+}(aq) + 2\ NO(g)$
- Is charge balanced? Are oxygen atoms balanced?

Problem 71-a in acid soln

- $3\ Cu(s) + 2\ NO_3^-(aq) = 3Cu^{2+}(aq) + 2\ NO(g)$
- In acid solution: Hydrogen ions are available to balance charge, yielding water as needed.
- $3\ Cu(s) + 2\ NO_3^-(aq) + 8H^+(aq) = 3Cu^{2+}(aq) + 2\ NO(g)$
- $3\ Cu(s) + 2\ NO_3^-(aq) + 8H^+(aq) = 3Cu^{2+}(aq) + 2\ NO(g) + 4H_2O(l)$
- In base solution, $OH^-(aq)$ would be available.

Hanson Activity 11-1

- Discuss Key Questions 1-7 of Activity 11-1, page 209, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

According to the ideal gas law, if the temperature increases while *n* and *V* remain unchanged, what happens to pressure?

33% 1. Decreases
33% 2. Remains unchanged
33% 3. Increases

According to the ideal gas law, if the volume increases while *n* and *T* remain unchanged, what happens to pressure?

1. Decreases
2. Remains unchanged
3. Increases

According to the ideal gas law, if the number of molecules in the container increases while *P* and *T* remain unchanged, what happens to volume?

- 33% 1. Decreases
- 33% 2. Remains unchanged
- 33% 3. Increases

According to the ideal gas law, if the number of molecules in the container increases while *V* and *T* remain unchanged, what happens to pressure?

- 33% 1. Decreases
- 33% 2. Remains unchanged
- 33% 3. Increases

At what temperature does an ideal gas exert no pressure?

- 33% 1. 273.15 K
- 33% 2. Zero Kelvin
- 33% 3. Zero Celsius

Exercise 1, page 209 at Projector

Calculate a value for R and determine its units using the following data:

n = 1.000 mole

P = 0.1300 atm

V = 172.42 L

T = 273.15 K

Answer: R = 0.08206 L-atm/mol-K

Do Ex 2, p210, with partner

- What is the volume?
- 22.4 L for 1 mole at STP

Do Got it #1, p210, with partner

- What are the answers?

Do
Got it #2, p210, with partner

- What are the answers?

Problem #2, p. 211 with partner

- Draw the experimental setup first!
- Strategy: treat each gas separately.
- $P_T = P_1 + P_2 = 2.8$ atm + 6.0 atm = 8.8 atm

Problem #3, p. 212 with partner

- What is the relationship between moles of a gas (n), its mass (m), and molar mass (M)?
- What is the relationship between moles of a gas(n), its pressure , volume, and temperature?

$$n = \frac{m}{M} \qquad n = \frac{PV}{RT} \qquad \frac{m}{V} = \frac{PM}{RT}$$

Problem #4, p. 212 with partner

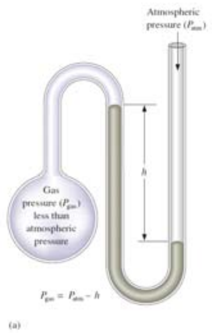
- First obtain the molar mass M of this compound, using the relationship from Problem 3

Problem #4, p. 212 with partner

- If M = 32.0 g/mol
- The compound contains only N and H
- The compound is 87.4% N by mass
- What is the molecular formula?

PV = nRT

- The only gas law to be memorized
- If n and T are constant: PV = k (Boyle)
- If P and n are constant: V = (nR/P)T = bT (Charles)
- If T and P are constant: V = n (RT/P) = an (Avogadro)



V = 22.41 L for ideal gas

TABLE 5.2

Molar Volumes for Various Gases at 0°C and 1 atm

Gas	Molar Volume (L)
Oxygen (O_2)	22.397
Nitrogen (N_2)	22.402
Hydrogen (H_2)	22.433
Helium (He)	22.434
Argon (Ar)	22.397
Carbon dioxide (CO_2)	22.260
Ammonia (NH_3)	22.079

Hanson Activity 11-3

- Discuss Key Questions 1-6 of Activity 11-3, page 220, with your partner for five minutes.
- The clicker quiz will commence in 5 minutes

Clicker quiz

- You may refer to your Hanson workbook
- Answer the questions individually
- In each case indicate the best answer
- No paper responses will be accepted

Partial Pressures (Dalton)

- Consider a container with two ideal gases.
- The pressures are independent of each other:
- $P_T = P_1 + P_2$
- Treat each pressure by ideal gas law:
- $P_T = n_1(RT/V) + n_2(RT/V) =$
  $(n_1+n_2)(RT/V) = n_T(RT/V)$

Partial Pressures (Dalton)

- $P_T = n_1(RT/V) + n_2(RT/V) = P_1 + P_2 =$
  $(n_1+n_2)(RT/V) = n_T(RT/V)$
- The *mole fraction* of a gas is the ratio of number of moles of that gas to the total number of moles.
- $\chi_1 = n_1/n_{T,\text{ and}}\ \chi_2 = n_2/n_{T,}$
- $P_1 = \chi_1 P_T$ and $P_2 = \chi_2$

Exercise 1 at projector

- $\chi(O_2)$ = 0.209 in air
- What are partial pressures of oxygen and nitrogen when P=755 torr?
- 158 and 597 torr

Do Exercise #2 with partner

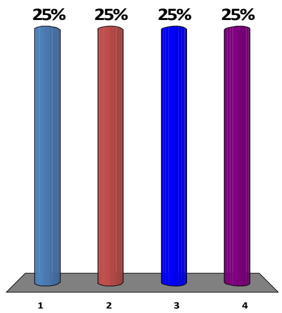
- Remember: nitrogen and oxygen are independent in this model.

Problem #1, p. 221

- 1st – calculate the total pressure in the cylinder
- 2nd – calculate the mole fractions of each gas
- 3rd – calculate the partial pressure of each gas

What is the total pressure?

1. 2.33 atm
2. 4.66 atm
3. 7.00 atm
4. 9.33 atm



- Finish problem #1

$$\chi_i = n_i/n_{total} = P_i/P_{total}$$

$P(CO_2)$ = 2.33 atm

$P(N_2)$ = 4.67 atm

- Problem #2: start by calculating the partial pressure of oxygen in the tank
  - How many moles of oxygen?
  - What is its partial pressure?
  - Repeat for nitrogen and add partial pressures to get total pressure

P_T = 16 atm.

Problem #3, page 222

$2\ KClO_3(s) = 2\ KCl(s) + 3\ O_2(g)$

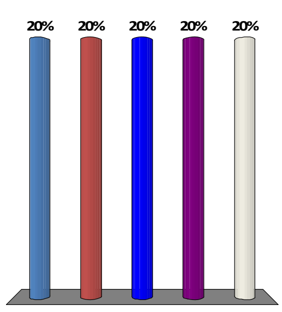
- Oxygen is collected over water.
- Gas contains the oxygen generated plus the equilibrium vapor pressure of water at this temp.

Problem #3, page 222

- Oxygen is collected over water.
- Gas contains the oxygen generated plus the equilibrium vapor pressure of water at this temp.
- 1st: what is the partial pressure of oxygen?
- 2nd: How many moles of oxygen
- 3rd: How many moles of potassium chlorate?

What is the partial pressure of oxygen?

1. 755.3 torr
2. 23.8 torr
3. 779.1 torr
4. 731.5 torr
5. 760 .0 torr



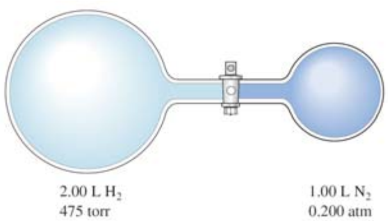
Problem #3, page 222

- 1st: what is the partial pressure of oxygen?
- 2nd: How many moles of oxygen?
- 0.0394 mol O_2
- 3rd: How many moles of potassium chlorate?
- 0.0262 mol $KClO_3$

Problem 5-29

317 torr H_2; 50.7 torr N_2

- What are final partial pressures of H_2 and N_2.
- V_f = 3.00 L.



Problem 5-37

970 K

- Bursts at 2500 torr
- T = 21.0 °C
- P = 758 torr
- Then heated
- At what Temp will it burst?

Problem 5-57

- Sample of CH_4 contains small amount of He
- Density = 0.70902 g/L at 0.0°C and 1.000 atm
- What is the volume % of He?
- 98.84% methane

Problem 4-59

- $Fe(s) + H_2SO_4(aq) = FeSO_4(aq) + H_2(g)$
- Volume of hydrogen = 4800 m^3 x 1.20 =?
- T=0°C, and P = 1.0 atm: moles of H_2?
- What mass of iron was needed?
- 1.5×10^7 g Fe

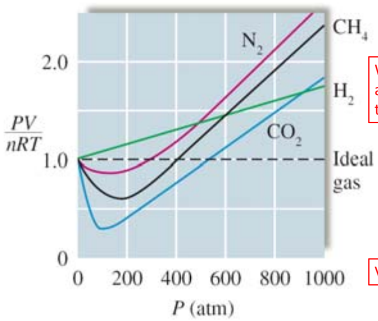
Real Gases vs Ideal Gases

- For an ideal gas:

$$PV = nRT$$

$$\frac{PV}{nRT} = 1$$

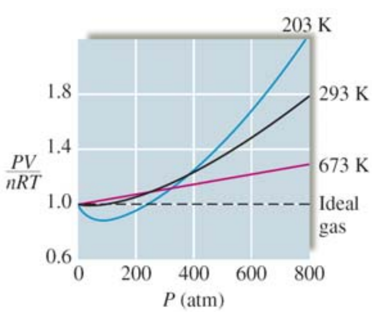
Real Gases



What is interesting about H_2 compared to these others?

Very high pressures

Real Gases: N_2



How does nonideality change with temperature?

Very high pressures

Real Gases: van der Waals

$$P = \frac{nRT}{V} \quad \text{(for ideal case)}$$

b represents the volume unavailable due to volume of the actual molecules. It is a *molar* quantity. For example, for N_2 it is 0.0391 L/mol

How do we expect b to vary from gas to gas?

Real Gases: van der Waals

$PV = nRT \quad \text{(for ideal case)}$

$P' = \frac{nRT}{V - nb} \quad \text{(correction : measured V is too large)}$

P' would be observed if molecules have volume but are noninteracting.
Real molecules attract each other, giving lower pressure.
$P_{obs} < P'$, *and we introduce a correction factor*
$P_{obs} = P' - P''$

Real Gases: van der Waals

$PV = nRT \quad \text{(for ideal case)}$

$P' = \frac{nRT}{V - nb} \quad \text{(correction : measured V is too large)}$

$P_{obs} = P' - P''$

Correction factor P" is proportional to the <u>square</u> of the molecule density, because the number of collisions is thusly proportional:
$\sim(n/V)^2$

$$P_{obs} = P' - P'' = \frac{nRT}{V - nb} - a\left(\frac{n}{V}\right)^2 \quad \text{(measured P is too small)}$$

Real Gases: van der Waals

$PV = nRT \quad \text{(for ideal case)}$

$P' = \frac{nRT}{V - nb} \quad \text{(correction : measured V is too large)}$

$$P_{obs} = \frac{nRT}{V - nb} - a\left(\frac{n}{V}\right)^2 \quad \text{(P is reduced by interactions)}$$

Real Gases: van der Waals

$PV = nRT$ (for ideal case)

$P' = \frac{nRT}{V - nb}$ (correction : measured V is too large)

$\left[P_{obs} + a\left(\frac{n}{V}\right)^2\right](V - nb) = nRT$ (van der Waals)

a represents the pressure reduction due to attraction between the actual molecules. It is a *molar* quantity. For example, for N_2 it is 1.39 atm L^2/mol^2

What magnitude is $(n/V)^2$

How do we expect a to vary from gas to gas?

TABLE 5.3

Values of van der Waals Constants for Some Common Gases

Gas	$a\left(\frac{atm\ L^2}{mol^2}\right)$	$b\left(\frac{L}{mol}\right)$
He	0.034	0.0237
Ne	0.211	0.0171
Ar	1.35	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0511
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
CO_2	3.59	0.0427
CH_4	2.25	0.0428
NH_3	4.17	0.0371
H_2O	5.46	0.0305

- Do the values support the trends we predicted?

TABLE 5.3

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CO_2	3.59	0.0427
CH_4	2.25	0.0428
NH_3	4.17	0.0371
H_2O	5.46	0.0305

Problem 5-87

- 0.5000 mol N_2
- 1.000L flask
- 25.0°C
- What is the pressure?
- Ideal: 12.24 atm
- VDW: 12.13 atm
- Difference: 0.91%

TABLE 5.3

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CO_2	3.59	0.0427
CH_4	2.25	0.0428
NH_3	4.17	0.0371
H_2O	5.46	0.0305

Problem 5-93

- Of the molecules H_2, N_2, CO_2, and CH_4, predict which has the strongest intermolecular interactions.
- CO_2

TABLE 5.3

Values of van der Waals Constants for Some Common Gases

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Ar	1.35	0.0322
Kr	2.32	0.0398
Xe	4.19	0.0511
H_2	0.244	0.0266
N_2	1.39	0.0391
O_2	1.36	0.0318
Cl_2	6.49	0.0562
CO_2	3.59	0.0427
CH_4	2.25	0.0428
NH_3	4.17	0.0371
H_2O	5.46	0.0305

- What trend do you see regarding intermolecular interactions for the rare gases: He, Ne, Ar, Kr, and Xe
- The “heaviest” have the strongest interactions

Next Week: Week 7

- GA7