T13Q1: Level 1 (L.G. 6)

What is the molar mass of the compound, $Cu_3(PO_4)_2$?

A. 110.5 g/mol
B. 237.6 g/mol
C. 316.6 g/mol
D. 349.6 g/mol
E. 380.6 g/mol

1A																	8A
1 **H** 1.008	**2A**											**3A**	**4A**	**5A**	**6A**	**7A**	2 He 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 23.00	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.70	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

T13Q1: Solution

What is the molar mass of the compound, $Cu_3(PO_4)_2$?

A. 110.5 g/mol
B. 237.6 g/mol
C. 316.6 g/mol
D. 349.6 g/mol
E. 380.6 g/mol

$Cu_3(PO_4)_2$:
3 x Cu
2 x P
8 x O

$$3(63.55) + 2(30.97) + 8(16)$$
$$= 380.6\ \text{g/mol}$$

1A																	8A
1 **H** 1.008	2A											3A	4A	5A	6A	7A	2 He 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 23.00	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 3	20	21	22	23	24	25	26	27	28 **Ni** .70	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
Rb	**Sr**	**Y**	**Zr**	**Nb**	**Mo**	**Tc**	**Ru**	**Rh**	46 **Pd**	47 **Ag**	48 **Cd**	49 **In**	50 **Sn**	51 **Sb**	52 **Te**	53 **I**	54 **Xe**

molar mass = mass of 1 mole

T13Q2: Level 1 (L.G. 6)

The calcium sulfate used in gypsum is a hydrate (meaning that water is absorbed into the sulfate). The formula for gypsum is: $CaSO_4 \bullet 2H_2O$. How much would one mole of gypsum weight? In other words, what is its molar mass?

A. 172 g
B. 156 g
C. 147 g
D. 141 g
E. 136 g

1A																	8A
1 **H** 1.008	2A											3A	4A	5A	6A	7A	2 He 4.003
3 **Li** 6.941	4 **Be** 9.012											5 **B** 10.81	6 **C** 12.01	7 **N** 14.01	8 **O** 16.00	9 **F** 19.00	10 **Ne** 20.18
11 **Na** 23.00	12 **Mg** 24.31											13 **Al** 26.98	14 **Si** 28.09	15 **P** 30.97	16 **S** 32.06	17 **Cl** 35.45	18 **Ar** 39.95
19 **K** 39.10	20 **Ca** 40.08	21 **Sc** 44.96	22 **Ti** 47.90	23 **V** 50.94	24 **Cr** 52.00	25 **Mn** 54.94	26 **Fe** 55.85	27 **Co** 58.93	28 **Ni** 58.70	29 **Cu** 63.55	30 **Zn** 65.38	31 **Ga** 69.72	32 **Ge** 72.59	33 **As** 74.92	34 **Se** 78.96	35 **Br** 79.90	36 **Kr** 83.80
37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54

T13Q2: Solution

The calcium sulfate used in gypsum is a hydrate (meaning that water is absorbed into the sulfate). The formula for gypsum is: $CaSO_4 \bullet 2H_2O$. How much would one mole of gypsum weight? In other words, what is its molar mass?

A. $\boxed{172\text{ g}}$
B. 156 g
C. 147 g
D. 141 g
E. 136 g

$CaSO_4 \bullet 2H_2O$:

1 x Ca
1 x S
6 x O
4 x H

$40.08 + 32.06 + 6(16.00) + 4(1.008) = 172$ g/mol

1A																	8A
1 H 1.008	2A											3A	4A	5A	6A	7A	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.81	6 C 12.01	7 N 14.01	8 O 16.00	9 F 19.00	10 Ne 20.18
11 Na 23.00	12 Mg 24.31											13 Al 26.98	14 Si 28.09	15 P 30.97	16 S 32.06	17 Cl 35.45	18 Ar 39.95
19 K 39.10	20 Ca 40.08	21 Sc 44.96	22 Ti 47.90	23 V 50.94	24 Cr 52.00	25 Mn 54.94	26 Fe 55.85	27 Co 58.93	28 Ni 58.70	29 Cu 63.55	30 Zn 65.38	31 Ga 69.72	32 Ge 72.59	33 As 74.92	34 Se 78.96	35 Br 79.90	36 Kr 83.80
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe

T13Q3: Level 1 (L.G. 8)

How many moles of water are in 3.6 grams of water?

A. 2.6×10^{24} moles
B. 64.8 moles
C. 3.6 moles
D. 0.20 moles
E. 0.40 moles

1	8
H	O
1.008	16.00

T13Q3: Solution

How many moles of water are in 3.6 grams of water?

A. 2.6 x 10^{24} moles
B. 64.8 moles
C. 3.6 moles
D. 0.20 moles
E. 0.40 moles

1	8
H	O
1.008	16.00

M_W of water:

2(1.008 g/mol) + (16.00 g/mol) = 18 g/mol

Grams H_2O → Moles H_2O

$$3.6\ \cancel{g\ H_2O} \times \frac{1\ mol\ H_2O}{18\ \cancel{g\ H_2O}} = 0.20\ \boxed{mol\ H_2O}$$

Your answer will have units of moles of H_2O

T13Q4: Level 2 (L.G. 8)

How many grams of oxygen are there in 6.2 g of Li_3PO_4?

A. 0.054 grams
B. 0.21 grams
C. 3.43 grams
D. 6.86 grams

3	8	15
Li	O	P
6.94	16.00	30.97

T13Q4: Solution

How many grams of oxygen are there in 6.2 g of Li_3PO_4?

A. 0.054 grams
B. 0.21 grams
C. 3.43 grams
D. 6.86 grams

3	8	15
Li	O	P
6.94	16.00	30.97

$1Li_3PO_4 \rightarrow 3Li + 1P + 4O$

M_w of Li_3PO_4:
3(6.94 g/mol) + 30.97 g/mol + 4(16.00 g/mol) = 115.73 g/mol

Grams molecules → Moles molecules → Moles O atoms → Grams O

$$6.2\ \cancel{g\ Li_3PO_4} \times \frac{1\ \cancel{mole\ Li_3PO_4}}{115.73\ \cancel{g\ Li_3PO_4}} \times \frac{4\ \cancel{moles\ O}}{1\ \cancel{mole\ Li_3PO_4}} \times \frac{16\ \boxed{grams\ O}}{1\ \cancel{mole\ O}}$$

Your answer will have units of

T13Q5: Level 2 (L.G. 9)

How many molecules of water are in 4.1 grams of water?

A. 0.23 molecules
B. 1.4×10^{23} molecules
C. 2.5×10^{24} molecules
D. 4.4×10^{25} molecules

1	8
H	**O**
1.008	16.00

T13Q5: Solution

How many molecules of water are in 4.1 grams of water?

A. 0.23 molecules

B. $\boxed{1.4 \times 10^{23} \text{ molecules}}$

C. 2.5×10^{24} molecules

D. 4.4×10^{25} molecules

1 H 1.008	8 O 16.00

M_w of water:

2(1.008 g/mol) + (16.00 g/mol) = 18 g/mol

Grams molecules → Moles molecules → Particles (molecules)

$$4.1 \text{ g } \cancel{H_2O} \times \frac{1 \text{ mole } \cancel{H_2O}}{18 \text{ g } \cancel{H_2O}} \times \frac{6.022 \times 10^{23} \boxed{\text{molecules } H_2O}}{1 \text{ } \cancel{\text{mole}} \text{ } H_2O}$$

Your answer will have units of

T13Q6: Level 2 (L.G. 5)

How many fluorine molecules are there in a 38.00 g sample of fluorine gas?

9
F
19.000

A. **2.289×10^{25} molecules**
B. **6.023×10^{23} molecules**
C. **1.205×10^{24} molecules**
D. **2.553×10^{24} molecules**

T13Q6: Solution

How many fluorine molecules are there in a 38.00 g sample of fluorine gas?

9
F
19.000

A. 2.289×10^{25} molecules

B. $\boxed{6.023 \times 10^{23} \text{ molecules}}$

C. 1.205×10^{24} molecules

D. 2.553×10^{24} molecules

M_w of fluorine (F_2):
2(19g/mol) = 38 g/mol

Grams molecules → Moles molecules → Particles (molecules)

$$\cancel{38\ g\ F_2} \times \frac{1\ \cancel{mole}\ F_2}{\cancel{38\ g\ F_2}} \times \frac{6.023 \times 10^{23}\ \text{molecules}\ F_2}{1\ \cancel{mole}\ F_2}$$

T13Q7: Level 2 (L.G. 5)

How many fluorine atoms are there in a 38.00 g sample of fluorine gas?

9
F
19.000

A. 2.289×10^{25} atoms
B. 6.023×10^{23} atoms
C. 1.205×10^{24} atoms
D. 2.553×10^{24} atoms

T13Q7: Solution

How many fluorine atoms are there in a 38.00 g sample of fluorine gas?

- **A.** **2.289 x 10^{25} atoms**
- **B.** **6.023 x 10^{23} atoms**
- $\boxed{\textbf{C. } 1.205 \times 10^{24} \textbf{ atoms}}$
- **D.** **2.553 x 10^{24} atoms**

9
F
19.000

$$F_2 \rightarrow 2F$$

M_w of fluorine (F_2):
2(19g/mol) = 38 g/mol

Grams molecules → Moles molecules → Moles (atoms) → Particles (atoms)

Your answer will have units of

$$38\ g\ \cancel{F_2} \times \frac{1\ \cancel{mole}\ F_2}{38\ g\ \cancel{F_2}} \times \frac{2\ moles\ \cancel{F\ atoms}}{1\ \cancel{mole}\ F_2} \times \frac{6.023 \times 10^{23}\ \boxed{atoms\ F}}{1\ \cancel{mole\ F}\ atoms}$$

T13Q8: Level 2 (L.G. 8)

How many moles of sodium atoms are there in 6.3 grams of sodium carbonate?

6	8	11
C	O	Na
12.01	16.00	23.00

A. 0.06 moles
B. 0.12 moles
C. 7.2 x 10^{22} moles
D. 3.6 x 10^{22} moles

T13Q8: Solution

How many moles of sodium atoms are there in 6.3 grams of sodium carbonate?

Na_2CO_3

A. 0.06 moles
B. **0.12 moles**
C. 7.2×10^{22} moles
D. 3.6×10^{22} moles

6	8	11
C	O	Na
12.01	16.00	23.00

$$1Na_2CO_3 \rightarrow 2Na + 1C + 3O$$

M_W of Na_2CO_3:

2(23 g/mol) + (12.01 g/mol) + 3(16.00 g/mol)

= 106 g/mol

Grams molecules → Moles molecules → Moles Na atoms

$$6.3\text{ g } \cancel{Na_2CO_3} \times \frac{1\text{ } \cancel{\text{mol } Na_2CO_3}}{106\text{ g } \cancel{Na_2CO_3}} \times \frac{2\text{ } \boxed{\text{mol Na}}}{1\text{ } \cancel{\text{mol } Na_2CO_3}}$$

Your answer will have units of moles of Na

T13Q9: Level 3 (L.G. 8)

How many moles of ions are there in a sample that is 10 g of magnesium phosphate, $Mg_3(PO_4)_2$?

8	12	15
O	Mg	P
16.00	24.31	30.97

A. 5.0 moles
B. 0.49 moles
C. 0.19 moles
D. 0.038 moles

T13Q9: Solution

How many moles of ions are there in a sample that is 10 g of magnesium phosphate, $Mg_3(PO_4)_2$?

A. 5.0 moles
B. 0.49 moles
C. 0.19 moles
D. 0.038 moles

8 O 16.00	12 Mg 24.31	15 P 30.97

$3\ Mg^{2+}\ \&\ 2\ PO_4^{3-}$

5 ions per 1 molecule

M_w of magnesium phosphate:

$3(24.31) + 2(30.97) + 8(16.00) = 263\ g/mol$

Grams molecules → Moles molecules → Moles ions

$$10\ \cancel{g}\ Mg_3(PO_4)_2 \times \frac{1\ \cancel{mole}\ Mg_3(PO_4)_2}{263\ \cancel{g}\ Mg_3(PO_4)_2} \times \frac{5\ \boxed{moles\ ions}}{1\ \cancel{mole}\ Mg_3(PO_4)_2}$$

Your answer will have units of

T13Q10: Level 2 (L.G. 9)

How many C atoms are there in a sample of C_3H_8 that contains 6.59×10^{26} H atoms?

1	6
H	C
1.008	12.01

A. 1.98×10^{27} C atoms

B. 2.47×10^{26} C atoms

C. 4.94×10^{26} C atoms

D. 3.17×10^{24} C atoms

T13Q10: Solution Alternate

How many C atoms are there in a sample of C_3H_8 that contains 6.59 x 10^{26} H atoms?

A. 1.98 x 10^{27} C atoms

B. 2.47 x 10^{26} C atoms

C. 4.94 x 10^{26} C atoms

D. 3.17 x 10^{24} C atoms

1 H 1.008	6 C 12.01

$C_3H_8 \rightarrow 3C + 8H$

Do you need Avogadro's number in this calculation?

NOPE, can go directly from

H atoms ➔ C atoms

mole ratio = atom ratio

$$6.59 \times 10^{26}\ \cancel{H} \times \frac{\cancel{1\ \text{mole H}}}{\boxed{\cancel{6.022 \times 10^{23}}}\ \cancel{H}} \times \frac{3\ \cancel{\text{mole}}\ C}{8\ \cancel{\text{mole}}\ H} \times \frac{\boxed{\cancel{6.022 \times 10^{23}}}\ \text{atoms C}}{\cancel{1\ \text{mole C}}}$$

T13Q11: Level 2 (L.G. 9)

How many oxygen atoms are found in a 33 g sample of manganese(II) sulfite?

A. 1.44×10^{23} O atoms
B. 3.94×10^{23} O atoms
C. 4.44×10^{23} O atoms
D. 7.22×10^{23} O atoms

8	16	25
O	S	Mn
16.00	32.07	54.94

T13Q11: Solution

How many oxygen atoms are found in a 33 g sample of manganese(II) sulfite?

Manganese(II) sulfite: $MnSO_3$
➔ 1Mn + 1S + 3O

8 **O** 16.00	16 **S** 32.07	25 **Mn** 54.94

A. 1.44 x 10^{23} O atoms
B. 3.94 x 10^{23} O atoms
C. $\boxed{4.44 \times 10^{23} \text{ O atoms}}$
D. 7.22 x 10^{23} O atoms

M_w of $MnSO_3$:
54.94 g/mol + 32.07 g/mol + 3(16.00 g/mol) = 135.0 g/mol

Grams molecules → Moles molecules → Moles O atoms → Particles (O atoms)

Your answer will have units of

$$33\ \cancel{g}\ MnSO_3 \times \frac{1\ \cancel{mole}\ MnSO_3}{135\ \cancel{g}\ MnSO_3} \times \frac{3\ \cancel{mole}\ O}{1\ \cancel{mole}\ MnSO_3} \times \frac{6.022 \times 10^{23}\ \boxed{\text{atoms O}}}{1\ \cancel{mole}\ O}$$

8 pt challenge

How many moles of sodium atoms are there in 4.4 grams of sodium carbonate?

6	8	11
C	O	Na
12.01	16.00	23.00

A. 2.5×10^{22} moles
B. 5.0×10^{22} moles
C. 0.04 moles
D. 0.08 moles
E. 0.12 moles

Q0: Solution

How many moles of sodium atoms are there in 4.4 grams of sodium carbonate?

Na_2CO_3

A. 2.5×10^{22} moles
B. 5.0×10^{22} moles
C. 0.04 moles
D. 0.08 moles
E. 0.12 moles

6	8	11
C	O	Na
12.01	16.00	23.00

$$1Na_2CO_3 \rightarrow 2Na + 1C + 3O$$

M_W of Na_2CO_3:

$2(23\ g/mol) + (12.01\ g/mol) + 3(16.00\ g/mol)$
$= 106\ g/mol$

Grams molecules → Moles molecules → Moles Na atoms

$$4.4\ g\ \cancel{Na_2CO_3} \times \frac{1\ \cancel{mol\ Na_2CO_3}}{106\ g\ \cancel{Na_2CO_3}} \times \frac{\boxed{2\ mol\ Na}}{1\ \cancel{mol\ Na_2CO_3}}$$

Your answer will have units of moles of Na

T14Q1: Level 4 (L.G. 8)

An aqueous solution containing 7.60 g of lead(II) nitrate is added to an aqueous solution containing 7.39 g of potassium chloride. If the percent yield is 84.0%, how many grams of excess reagent remain after the reaction is complete?

A. **5.66 g**
B. **4.50 g**
C. **3.33 g**
D. **0.0604 g**

T14Q1: Solution

An aqueous solution containing 7.60 g of lead(II) nitrate is added to an aqueous solution containing 7.39 g of potassium chloride. If the percent yield is 84.0%, how many grams of excess reagent remain after the reaction is complete?

$$Pb(NO_3)_2(aq) + 2KCl(aq) \rightarrow PbCl_2(s) + 2KNO_3(aq)$$

$Pb(NO_3)_2$	KCl
7.6 g /(331.12 g/n) = 0.023 moles	7.39 g /(74.55g/n) = 0.099 moles
$\boxed{0.023 \text{ n x } (1/1) = 0.023 \text{ moles } PbCl_2}$	0.099 n x (1/2) = 0.0495 moles $PbCl_2$
Moles KCl reacted = 0.023 x (2/1) x (84%/100%) = 0.0386 moles	
Excess KCl (moles) = 0.099 moles - 0.0386 moles = 0.0604 moles	
Excess KCl (grams) = 0.0604moles x (74.55 g/mol) = 4.50 grams KCl	

T14Q2: Level 1 (L.G. 2)

Consider the reaction: **$2H_2 + O_2 \rightarrow 2H_2O$**

If 3 moles of H_2 react with 2 moles of O_2, what is the maximum number of moles of H_2O that can be produced?

A. **5 moles**

B. **4 moles**

C. **3 moles**

D. **2 moles**

T14Q2: Solution

Consider the production of Iron from magnetite (Fe_3O_4):

$Fe_3O_4(s) + 2CO(g) \rightarrow 3Fe(s) + 2CO_2(g) + O_2(g)$

What mass of magnetite is required to obtain 4.0 kg of iron if the process only runs to 66% completion?

We know that: % yield = actual product (g)/theoretical yield (g) X 100%

Rearrange Eq: theoretical yield (g) = actual product (g)/ % yield X 100%

Fe_3O_4	3Fe(s)
Theoretical yield = (4000 g Fe)*100/(66) = 6060 g Fe	
6060 g Fe / (55.85 g/mol) = 108.5 moles Fe	
108.5 n x (1/3) = 36.17 n Fe_3O_4	-
36.17 n x (231.55 g/n) = 8375 g Fe_3O_4	-

T14Q3: Level 2 (L.G. 3)

How many moles of O_2 are required for the complete combustion of 2.2 g of C_3H_8 to form CO_2 and H_2O?

A. **0.050 moles of O_2**
B. **0.15 moles of O_2**
C. **0.25 moles of O_2**
D. **0.50 moles of O_2**

T14Q3: Solution

How many moles of O_2 are required for the complete combustion of 2.2 g of C_3H_8 to form CO_2 and H_2O?

A. 0.050 moles of O_2
B. 0.15 moles of O_2
C. $\boxed{\text{0.25 moles of } O_2}$
D. 0.50 moles of O_2

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

M_w of C_3H_8
= 3(12.01 g/mol) + 8(1.008 g/mol)
= 44.1 g/mol

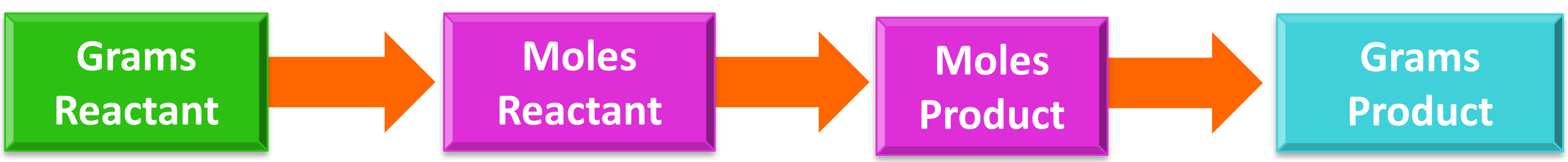
Reaction	C_3H_8 +	$5O_2$	$\rightarrow$ $3CO_2 + 4H_2O$
In the vessel before rxn (no coefficient used)	2.2 g	-	-
	2.2 g /(44.1 g/n) = 0.049 moles	?	-
What reacted	0.049 moles	0.049 moles x (5/1) = 0.25 moles	-

T14Q4: Level 3 (L.G. 4)

Calculate the maximum amount of aluminum oxide (Al_2O_3) that could be produced if 2.5 g of Al react with 2.5 g of oxygen .

A. **4.7 g**
B. **5.3 g**
C. **7.4 g**
D. **9.4 g**

Before doing any math:
We need to write a balanced equation for the reaction



T14Q4: Solution

Consider the production of Iron from magnetite (Fe_3O_4):

$Fe_3O_4(s) + 2CO(g) \rightarrow 3Fe(s) + 2CO_2(g) + O_2(g)$

What mass of magnetite is required to obtain 5.0 kg of iron if the process only runs to 88% completion?

Percent yield = (Actual yield/theoretical yield) * 100%

Fe_3O_4	3Fe
Theoretical yield = (5000 g Fe)*100%/88% = 5681 g Fe	
5681 g Fe / (55.85 g/mol) = 101.73 moles Fe	
101.73 n x (1/3) = 33.91 n Fe_3O_4	-
33.91 n x (231.55 g/n) = 7851 g Fe_3O_4	-

T14Q5: Level 2 (L.G. 4)

For the reaction $\mathbf{N_2 + 3H_2 \rightarrow 2NH_3}$,
If you react 21 g hydrogen with 56 g nitrogen, what is the maximum number of grams of NH_3 that can be formed?

- **A.** **34 g**
- **B.** **68 g**
- **C.** **70 g**
- **D.** **79 g**

7	**1**
N	**H**
14.01	**1.008**

T14Q5: Solution

For the reaction $N_2 + 3H_2 \rightarrow 2NH_3$, Step 1
If you react 21 g hydrogen with 56 g nitrogen, what is the maximum number of grams of NH_3 that can be formed?

Step 2

21 g H_2 / (2.016 g/mol) $\rightarrow$ 10.41 moles H_2
56 g N_2 / (28.02g/mol) $\rightarrow$ 1.99 moles N_2

7	1
N	H
14.01	1.008

Step 3

Ratio H_2 to NH_3 is 3:2
10.41 moles H_2 * ($2NH_3$ /$3H_2$) = 6.94 moles NH_3
Ratio N_2 to NH_3 is 1:2
1.99 moles N_2 * ($2NH_3$ / $1N_2$) = 3.98 moles NH_3

N_2 is the limiting reagent

Step 4

(3.98 moles NH_3) * (17.034 g/mol) = <u>67.8 grams NH_3</u>

T14Q6: Level 2 (L.G. 4)

Consider the chemical reaction that occurs when iron(III) oxide reacts with carbon to produce iron metal and carbon dioxide: **$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$** If 13.00 g of Fe_2O_3 reacts completely with 4.20 g of C, how much Fe will be formed?

A. 26.08 g
B. 19.54 g
C. 9.05 g
D. 4.52 g
E. 2.26 g

Grams L.R → Moles L.R → Moles Product → Grams Product

T14Q6: Solution

Consider the chemical reaction that occurs when iron(III) oxide reacts with carbon to produce iron metal and carbon dioxide: **$2Fe_2O_3 + 3C \rightarrow 4Fe + 3CO_2$** If 13.00 g of Fe_2O_3 reacts completely with 4.20 g of C, how much Fe will be formed?

Fe_2O_3	C
13 g /(159.7 g/mol) = 0.081 moles	4.2 g /(12.01 g/mol) = 0.350 moles
0.081 n x (4/2) = 0.162 moles Fe	0.350 n x (4/3) = 0.467 moles Fe
Theoretical Yield: (grams of product formed if all LR reacts) 0.162 moles x (55.85 g/mol) = 9.05 grams Fe	

T14Q7: Level 3 (L.G. 8)

Consider the chemical reaction that occurs when sodium metal reacts with oxygen gas: **$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$**
How many grams of sodium oxide are produced when 5.00 g of sodium and 5.00 g of oxygen react and a 84% yield of sodium oxide is obtained.

A. **5.64 grams**
B. **6.73 grams**
C. **8.33 grams**
D. **9.92 grams**

T14Q7: Solution

Consider the chemical reaction that occurs when sodium metal reacts with oxygen gas: **$4Na(s) + O_2(g) \rightarrow 2Na_2O(s)$**
How many grams of sodium oxide are produced when 5.00 g of sodium and 5.00 g of oxygen react and a 84% yield of sodium oxide is obtained.

Na	**O_2**
5 g /(23 g/mol) = 0.217 moles	**5 g /(32g/mol) = 0.16 moles**
0.217 n x (2/4) = 0.1085 moles Na_2O	**0.16 n x (2/1) = 0.32 moles Na_2O**
Theoretical Yield: 0.1085 moles x (61.98 g/mol) = 6.73 grams Na_2O	
Actual yield = (6.73 g)*(84%/100%) = 5.64 g Na_2O	

T14Q8: Level 3 (L.G. 8)

Consider the following chemical reaction:

$NaHCO_3(aq) + HCl(aq) \rightarrow H_2CO_3\,(aq) + NaCl(aq)$

How many grams of hydrogen carbonate are produced if you react 2.8 g of sodium hydrogen carbonate with 3.1 g of hydrochloric acid and the yield is 45%.

A. 5.27 grams
B. 2.37 grams
C. 2.07 grams
D. 0.93 grams

Grams L.R → Moles L.R → Moles Product → Grams Product → % Yield Calculation

T14Q8: Solution

Consider the following chemical reaction:

$NaHCO_3$(aq) + HCl(aq) → H_2CO_3 (aq)+ NaCl(aq)

How many grams of hydrogen carbonate are produced if you react 2.8 g of sodium hydrogen carbonate with 3.1 g of hydrochloric acid and the yield is 45%.

$NaHCO_3$	HCl
2.8 g /(84.007 g/mol) = 0.033 moles	**3.1 g /(36.46g/mol) = 0.085 moles**
0.033 n x (1/1) = 0.033 moles H_2CO_3	0.085 n x (1/1) = 0.085 moles H_2CO_3
Theoretical Yield: **0.033 moles x (62.03 g/mol) = 2.07 grams H_2CO_3**	
Actual yield = (2.07 g)*(45%/100%) = 0.93 g H_2CO_3	

T14Q9: Level 3 (L.G. 8)

When 2.5 moles of calcium carbonate is added to 4.8 moles of hydrochloric acid, calcium chloride, carbon dioxide, and water are produced: **$CaCO_3(s)$ + $2HCl(aq)$ → $CaCl_2(aq)$ + $H_2O(l)$ + $CO_2(g)$**
Which calculation represents the number of *grams* of calcium chloride that are produced if the reaction proceeds with a 65% yield?

A. **2.5 moles $CaCl_2$ * 110.98 grams/mol * 0.65**
B. **2.4 moles $CaCl_2$ * 110.98 grams/mol * 0.65**
C. **2.5 moles $CaCl_2$ * 110.98 grams/mol / 0.65**
D. **2.4 moles $CaCl_2$ * 110.98 grams/mol / 0.65**

T14Q9: Solution

B. 2.4 moles $CaCl_2$ * 110.98 grams/mol * 0.65

$$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + H_2O(l) + CO_2(g)$$

2.5 moles 4.8 moles 65% yield

2.5 moles $CaCO_3$ x (1/1) = 2.5 moles $CaCl_2$

4.8 moles HCl x (1/2) = 2.4 moles $CaCl_2$

HCl is the limiting reagent and you can only make 2.4 moles of $CaCl_2$

Moles LR → Moles Product → Grams Product → % Yield Calculation

$$2.4 \text{ moles } CaCl_2 \times \frac{110.98 \text{ g } CaCl_2}{1 \text{ mole } CaCl_2} \times \frac{65\ \%}{100\%}$$

8 pt Challenge: Solution

Once vanadium has been extracted from vanadinite ore it can be used to produce a variety of pure vanadium oxides. One such oxide was found to contain 56.02% vanadium. What is the empirical formula of this oxide?

Species	V	O
%	**56.02 %**	**100 - 56.02 = 43.98%**
Grams	**56.02**	**43.98**
Moles	56.02/(50.94 g/mol) **= 1.09 mol**	43.98/(16 g/mol) **= 2.75 mol**
Mole Ratio	1.09/1.09 **= 1**	2.75/1.09 **= 2.52**

x 2

V_2O_5

T15Q1: Level 2 (L.G. 1)

How many grams of sodium are in 23 g of sodium sulfate?

8	11	16
O	Na	S
16.00	22.99	32.06

A. **32 g**
B. **7.45 g**
C. **6.57 g**
D. **3.73 g**
E. **0.710 g**

T15Q1: Solution

How many grams of sodium are in 23 g of sodium sulfate?

A. 32 g
B. 7.45 g
C. 6.57 g
D. 3.73 g
E. 0.710 g

sodium sulfate:
Na_2SO_4

8	11	16
O	Na	S
16.00	22.99	32.06

M_w Na_2SO_4= = 142.04 g/mol

% Na = [2(22.99 g/mol)]/(142.04/mol)]* 100%
= 32.37 %

Grams Na = (% Na in Na_2SO_4) x mass of Na_2SO_4
= (32.37/100) x 23 g
= 7.45 g

Can do this is a single step:
Grams Na = [2(22.99 g/mol)]/(142.04/mol)] x 23g = 7.45g

T15Q2: Level 1 (L.G. 1)

The percent water in the hydrate $CuSO_4 \cdot 6H_2O$ is:

1	8	16	29
H	O	S	Cu
1.008	16.00	32.06	63.55

A. **40.4%**
B. **6.73%**
C. **9.60%**
D. **57.6%**

T15Q2: Solution

The percent water in the hydrate $CuSO_4{\cdot}6H_2O$ is:

A. 40.4%
B. 6.73%
C. 9.60%
D. 57.6%

1	8	16	29
H	O	S	Cu
1.008	16.00	32.06	63.55

$$\% \text{ Comp.} = \frac{\text{Mass of element in compound}}{\text{Total mass of compound}} \times 100\%$$

M_w H_2O = 18.02 g/mol

M_w $CuSO_4{\bullet}6H_2O$

= 63.55 g/mol + 32.06 g/mol + 4(16.00 g/mol) + 6(18.02 g/mol)

= 267.73 g/mol

% H_2O = [6(18.02 g/mol)]/(267.73/mol)]* 100 %

= 40.38 %

T15Q3: Level 3 (L.G. 4)

Combustion of a 0.9835 g sample of a compound containing only C, H, and O produced 1.900 g of CO_2 and 1.072 g of H_2O. What is the empirical formula of the compound?

A. C_2H_5O
B. $C_2H_5O_2$
C. $C_4H_{10}O_2$
D. $C_4H_{11}O_2$

T15Q3: Solution

Combustion of a 0.9835 g sample of a compound containing only C, H, and O produced 1.900 g of CO_2 and 1.072 g of H_2O. What is the empirical formula of the compound?

$$C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$$

$$\frac{0.518\ \text{g C}}{12.01\ \text{g/mol}} \qquad \frac{0.120\ \text{g H}}{1.008\ \text{g/mol}} \qquad \frac{0.345\ \text{g O}}{16.00\ \text{g/mol}}$$

$$\frac{C_{0.0432}\ \ H_{0.120}\ \ O_{0.0216}}{0.0216 \qquad 0.0216 \qquad 0.0216}$$

$$\left(C_{2.00}H_{5.51}O_{1}\right) \times 2 \rightarrow C_4H_{11}O_2$$

T15Q4: Level 3 (L.G. 4)

An unknown compound has the formula $C_xH_yO_z$. When 0.200 g of the compound is burned in oxygen you isolate 0.293 g of CO_2 and 0.120 g of H_2O. If the experimentally determined molar mass of the compound is 60.07 g/mol, what is its molecular formula?

- **A.** CH_2O
- **B.** $C_2H_4O_2$
- **C.** $C_2H_2O_2$
- **D.** C_2H_2O

T15Q4: Solution

An unknown compound has the formula $C_xH_yO_z$. When 0.200 g of the compound is burned in oxygen you isolate 0.293 g of CO_2 and 0.120 g of H_2O. If the experimentally determined molar mass of the compound is 60.07 g/mol, what is its molecular formula?

Atom	C	H	O
Mass (grams)	(12.01/44.01) x 0.293 g **= 0.07996**	(2.016/18.02) x 0.120 g **= 0.01343**	0.2 - 0.07996 - 0.01343 **= 0.10661**
Moles	0.07996/12.01 **= 0.00666**	0.01343/1.008 **= 0.01332**	0.10661/16.00 **= 0.00666**
EF mole Ratio	0.00666/0.00666 **= 1**	0.01332/0.00666 **= 2.000**	0.00666/0.00666 **= 1.000**
	1	**2**	**1**

CH_2O

X 2

= $C_2H_4O_2$

Mass of EF: 12.01 + 2(1.008) + 16.00 = 30.026 g/mol

(60.07 g/mol)/(30.026 g/mol) = 2

T15Q5: Level 3 (L.G. 4)

Prior to their phaseout in the 1980s, chemicals containing lead were commonly added to gasoline as anti-knocking agents. A 8.943 g sample of one such additive containing only lead, carbon and hydrogen was burned in an oxygen rich environment. The products of the combustion were 9.795 g of CO_2 and 5.035 g of H_2O. The *sum* of the subscripts in the empirical formula of the lead additive is:

A. **36**
B. **30**
C. **29**
D. **26**

T15Q5: Solution

A **8.943 g** sample containing only lead, carbon and hydrogen was burned in an oxygen rich environment. The products of the combustion were **9.795 g of CO_2 and 5.035 g of H_2O**.

Atom	Pb	C	H
Mass (grams)	8.943 – 2.673 – 0.563 **= 5.707**	(12.01/44.01) x 9.795g **= 2.673**	(2.016/18.015) x 5.035 g **= 0.563**
Moles	5.707/207.2 **= 0.028**	2.673/12.01 **= 0.223**	0.563/1.008 **= 0.559**
EF mole Ratio	0.028/0.028 **= 1**	0.223/0.028 **= 7.96**	0.559/0.028 **= 19.96**
	1	**8**	**20**

1 + 8 + 20 = 29

T15Q6: Level 3 (L.G. 2)

Carnotite (**$K_2(UO_2)_2(VO_4)_2$**) and is one of 3 common vanadium ores. Vanadium metal can be extracted from this ore as pure vanadium. If you start with 985 g of carnotite, what is the maximum number of grams of V that can be extracted?

A. **59.2 grams**
B. **98.5 grams**
C. **118 grams**
D. **120 grams**
E. **130 grams**

T15Q6: Solution

Carnotite (**$K_2(UO_2)_2(VO_4)_2$**) and is one of 3 common vanadium ores. Vanadium metal can be extracted from this ore as pure vanadium. If you start with 985 g of carnotite, what is the maximum number of grams of V that can be extracted?

A. 59.2 grams
B. 98.5 grams
C. 118 grams
D. 120 grams
E. 130 grams

% V in $K_2(UO_2)_2(VO_4)_2$:

$=[(\#V)(M_w\ V)/M_w\ K_2(UO_2)_2(VO_4)_2\ ] \times 100\%$

$= [2(50.94)/(848.12\ g/mol)] \times 100\%$

$= 12.01\%$

Mass of V that can be extracted:

$= (12.01/100) \times (985\ g)$

$= 118.32\ g$

T15Q9: Level 4 (L.G. 1)

When an unknown hydrate of Na_2CO_3 is heated until all the water is removed, it looses 54.3% of its mass. What was the formula of the hydrate before it was heated?

A. Na_2CO_3
B. $Na_2CO_3 \bullet 1H_2O$
C. $Na_2CO_3 \bullet 5H_2O$
D. $Na_2CO_3 \bullet 7H_2O$

T15Q9: Solution Alternative (no table)

When an unknown hydrate of Na_2CO_3 is heated until all the water is removed, it looses 54.3% of its mass. What was the formula of the hydrate before it was heated?

A. Na_2CO_3
B. $Na_2CO_3 \bullet 1H_2O$
C. $Na_2CO_3 \bullet 5H_2O$
D. $\boxed{Na_2CO_3 \bullet 7H_2O}$

$Na_2CO_3 \bullet XH_2O$ What is X?

Mass of XH_2O is 54.3%

Mass of Na_2CO_3 is (100 – 54.3) = 45.7%

$M_w(Na_2CO_3)$ = 106.01 g/mol

$M_w(H_2O)$ = 18.02 g/mol

45.7 % = 106.01 g/mol

100% = X

X = total mass

= 106.01g/mol x (100/45.7)

= 231.95 g/mol

Mass of XH_2O = total - Na_2CO_3 mass

= 231.95 – 106.01

= 125.96 g/mol

Mol of H_2O = mass/Mw

= 125.96/18.02

X = 6.99 = 7

T15Q12: Level 3 (L.G. 1)

Vanadinite (**$Pb_5(VO_4)_3Cl$**) and is one of the main industrial ores that are used for the extraction of elemental vanadium.
If you start with 1.21 kg of $Pb_5(VO_4)_3Cl$, what is the maximum number of grams of V that can be extracted from this ore.

A. **43.2 grams**
B. **130 grams**
C. **155 grams**
D. **173 grams**

T15Q12: Solution

Vanadinite (**$Pb_5(VO_4)_3Cl$**) and is one of the main industrial ores that are used for the extraction of elemental vanadium.
If you start with 1.21 kg of $Pb_5(VO_4)_3Cl$, what is the maximum number of grams of V that can be extracted from this ore.

A. **43.2 grams**
B. **130 grams**
C. **155 grams**
D. **173 grams**

% V in $Pb_5(VO_4)_3Cl$:

$=[(\#V)(M_w\ V)/M_w\ Pb_5(VO_4)_3Cl\ ] \times 100\%$

$= 3(50.94)/(1416.27\ g/mol) \times 100\%$

$= 10.79\%$

Mass of V that can be extracted:

$= (10.79/100) \times (1.21\ kg) * (1000g/1kg)$

$= 130.5\ g$

T16Q1: Level 3 (L.G. 12)

How many of the following molecules exhibit H-bonds, how many exhibit dipole-dipole interactions and how many exhibit London Dispersion forces respectively?

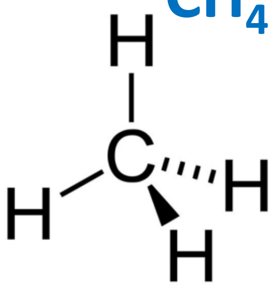
CH_4 **CH_3OH** **H_2S** **NH_3**

A. **1, 2 and 4**
B. **2, 2 and 4**
C. **2, 3 and 4**
D. **2, 0 and 2**
E. **1, 2 and 1**

T16Q1: Solution

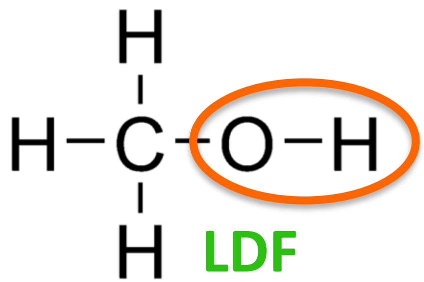
How many of the following molecules exhibit H-bonds, how many exhibit dipole-dipole interactions and how many exhibit London Dispersion forces respectively?

CH_4



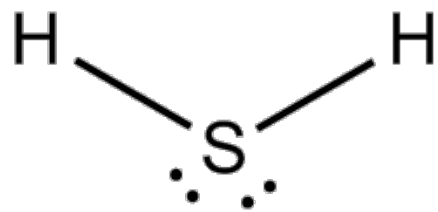
LDF

CH_3OH



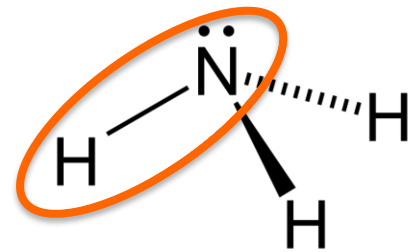
LDF
D-D
H-Bonds

H_2S



LDF
D-D

NH_3



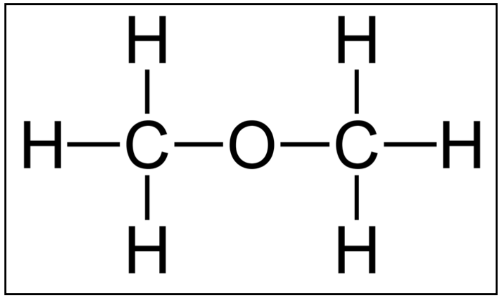
LDF
D-D
H-Bonds

A. 1, 2 and 4
B. 2, 2 and 4
C. $\boxed{\text{2, 3 and 4}}$
D. 2, 0 and 2
E. 1, 2 and 1

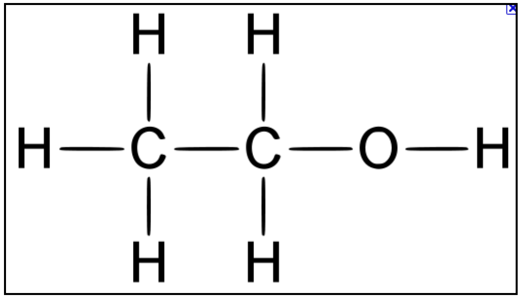
IMF are not mutually exclusive! Just because you have stronger forces like H-bonds, doesn't mean the D-D and LDFs go away

T16Q2: Level 2 (L.G. 12)

Which of the following has a higher boiling point and why?



Dimethyl ether (CH_3OCH_3)



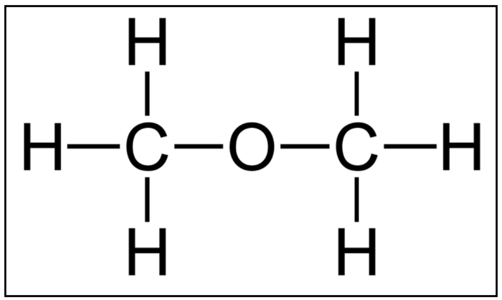
Ethanol (CH_3CH_2OH)

A. Dimethyl ether because it has LDF, dipole-dipole interactions and hydrogen bonds
B. Dimethyl ether because it has only LDF and dipole-dipole interactions
C. Ethanol because it has LDF, dipole-dipole interactions and hydrogen bonds
D. Ethanol because it has only LDF and dipole-dipole interactions

T16Q2: Solution

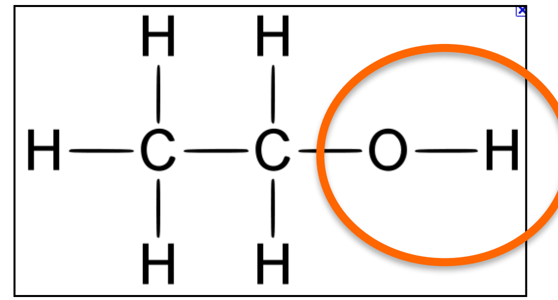
Which of the following has a higher boiling point and why?

POLAR



Dimethyl ether (CH_3OCH_3)

POLAR



Ethanol (CH_3CH_2OH)

A. Dimethyl ether because it has LDF, dipole-dipole interactions and hydrogen bonds

B. Dimethyl ether because it has only LDF and dipole-dipole interactions

As IMF's get stronger bp increases.

C. Ethanol because it has LDF, dipole-dipole interactions and hydrogen bonds

D. Ethanol because it has only LDF and dipole-dipole interactions

T16Q3: Level 2 (L.G. 12)

Based on the $\Delta H_{vaporization}$ values shown in the table below, which of the following compounds has the strongest intermolecular forces (IMF's)?

A. Argon
B. Benzene
C. Ethanol
D. Water
E. Methane

Substance	ΔH_{vap}
Argon (Ar)	6.3 kJ/mol
Benzene (C_6H_6)	31 kJ/mol
Ethanol (C_2H_5OH	39.3 kJ/mol
Methane (CH_4)	9.2 kJ/mol
Water (H_2O)	40.8 kJ/mol

T16Q3: Solution

Based on the $\Delta H_{vaporization}$ values shown in the table below, which of the following compounds has the strongest intermolecular forces (IMF's)?

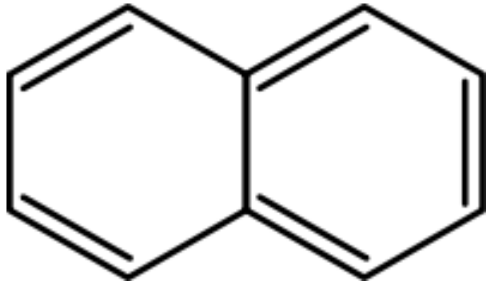
A. Argon
B. Benzene
C. Ethanol
D. $\boxed{\text{Water}}$
E. Methane

Substance	ΔH_{vap}
Argon (Ar)	6.3 kJ/mol
Benzene (C_6H_6)	31 kJ/mol
Ethanol (C_2H_5OH	39.3 kJ/mol
Methane (CH_4)	9.2 kJ/mol
Water (H_2O)	40.8 kJ/mol

ΔH_{vap} → energy required to vaporize a substance
Higher ΔH_{vap} corresponds to more energy required to go from liquid to gas → IMFs must be stronger

T16Q4: Level 3 (L.G. 12)

Napthalene ($C_{10}H_8$) is an organic molecule that has only LDF. How is it possible then that napthalene is a solid at room temperature, but water is a liquid?



A. **Molecules with stronger IMF always have have higher boiling points.**

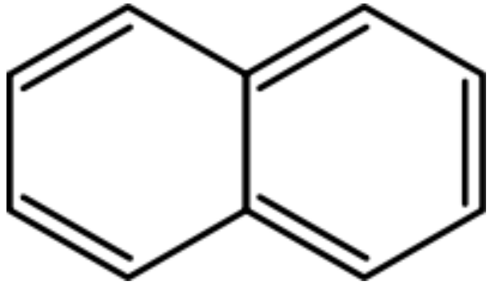
B. **Water molecules can form H-bonds so water must have stronger IMF than those of napthalene.**

C. **Napthalene is a large planar molecule and so its LDF's are stronger than the H-bond in water.**

D. **Molecules with stronger IMF are more likely to be solids at room temperature.**

T16Q4: Solution

Napthalene ($C_{10}H_8$) is an organic molecule that has only LDF. How is it possible then that napthalene is a solid at room temperature, but water is a liquid?



A. **Molecules with stronger IMF always have have higher boiling points.**

B. **Water molecules can form H-bonds so water must have stronger IMF than those of napthalene.**

C. **Napthalene is a large planar molecule and so its LDF's are stronger than the H-bond in water.**

D. **Molecules with stronger IMF are more likely to be solids at room temperature.**

Napthalene is a large planar molecule with a flat surface that allows for two molecules to interact in many positions and at a very close range!

T16Q5: Level 4 (L.G. 12)

Consider the molecules: H_2O, CO_2, NH_3, CCl_4. The boiling points of these four molecules from lowest boiling point to highest boiling point are -78°C, -34°C, 76°C, 100°C. Place these molecules in order from highest boiling point to lowest boiling point.
(**HINT:** Both NH_3 and CO_2 are gases at room temperature.)

- **A.** **H_2O, CCl_4, NH_3, CO_2**
- **B.** **H_2O, NH_3, CCl_4, CO_2**
- **C.** **NH_3, CO_2, CCl_4, H_2O**
- **D.** **H_2O, CCl_4, CO_2, NH_3**

T16Q5: Solution

Consider the molecules: H_2O, CO_2, NH_3, CCl_4. The boiling points of these four molecules from lowest boiling point to highest boiling point are -78°C, -34°C, 76°C, 100°C. Place these molecules in order from highest boiling point to lowest boiling point.
(**HINT:** Both NH_3 and CO_2 are gases at room temperature.)

A. $\boxed{H_2O, CCl_4, NH_3, CO_2}$

~~B. H_2O, NH_3, CCl_4, CO_2~~

~~C. NH_3, CO_2, CCl_4, H_2O~~

~~D. H_2O, CCl_4, CO_2, NH_3~~

You know the bp of H_2O is 100 so you know H_2O must be first.

NH_3 and CO_2 are gases, so they must have weaker IMF than CCl_4 which is a liquid.

NH_3 is polar and forms hydrogen bonds, whereas CO_2 only has LDF.

T16Q6: Level 3 (L.G. 12)

Pure samples of which of the following compounds will exhibit hydrogen bonding?

I. CH_3OH II. CH_3NO_3 III. CH_3CN

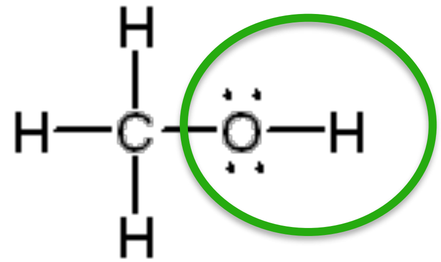
A. **I only**
B. **I and II only**
C. **II and III only**
D. **I, II and III**

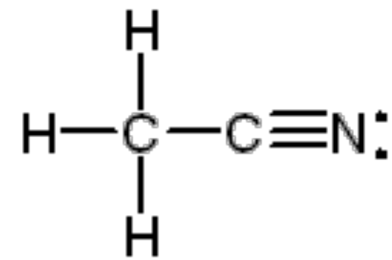
T16Q6: Solution

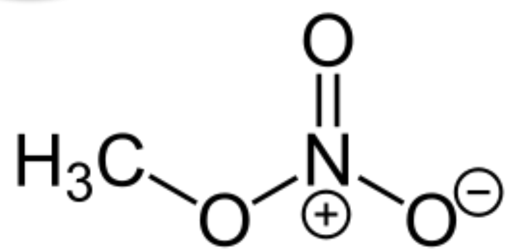
Pure samples of which of the following compounds will exhibit hydrogen bonding?

I. CH_3OH II. CH_3NO_3 III. CH_3CN

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







In order to form a hydrogen bond, a molecule must have a hydrogen attached to one of the following: O, N or F.

T16Q7: Level 2 (L.G. 12)

Which one of the following molecules is predicted to have the lowest boiling point?

A. H_2S
B. PH_3
C. HCl
D. SiH_4
E. H_2O

T16Q7: Solution

Which one of the following molecules is predicted to have the lowest boiling point?

A. H_2S
B. PH_3
C. HCl
D. SiH_4
E. H_2O

As BP increases IMF must get stronger.
SiH_4 is the only non-polar molecule thus it has the weakest IMFs (only LDFs).

Make sure you can draw all the Lewis structures and predict the polarity.

T16Q13: Level 2 (L.G. 11)

Which of the following statements is **not** characteristic of a hydrogen bond?

- **A.** **The other atom involved in the hydrogen bond (not the hydrogen atom) must be a very electronegative atom that is attached to another hydrogen atom.**
- **B.** **The other atom involved in the hydrogen bond (not the hydrogen atom) always possesses at least one lone pair of electrons.**
- **C.** **The hydrogen atom involved must be covalently bonded to a very electronegative atom.**
- **D.** **Hydrogen bonds are typically weaker than ionic or covalent bonds.**

T16Q13: Solution

Which of the following statements is **not** characteristic of a hydrogen bond?

Electronegative atom in H-bond: N, O or F

A. **The other atom involved in the hydrogen bond (not the hydrogen atom) must be a very electronegative atom that is attached to another hydrogen atom.**

B. **The other atom involved in the hydrogen bond (not the hydrogen atom) always possesses at least one lone pair of electrons.**

C. **The hydrogen atom involved must be covalently bonded to a very electronegative atom.**

D. **Hydrogen bonds are typically weaker than ionic or covalent bonds.**

T16Q14: Level 2 (L.G. 12)

The boiling point of water is about 200°C higher than one would predict from the boiling points of hydrogen sulfide and hydrogen selenide. One may explain this apparent anomaly by which of the following?

A. **The H-O covalent bond is much stronger than the H-S and H-Se bonds**
B. **Water has the lowest molecular weight**
C. **The intermolecular attractive forces are much greater in water than in hydrogen sulfide and hydrogen selenide.**
D. **Water is less polar than hydrogen sulfide and hydrogen selenide.**

T16Q14: Solution

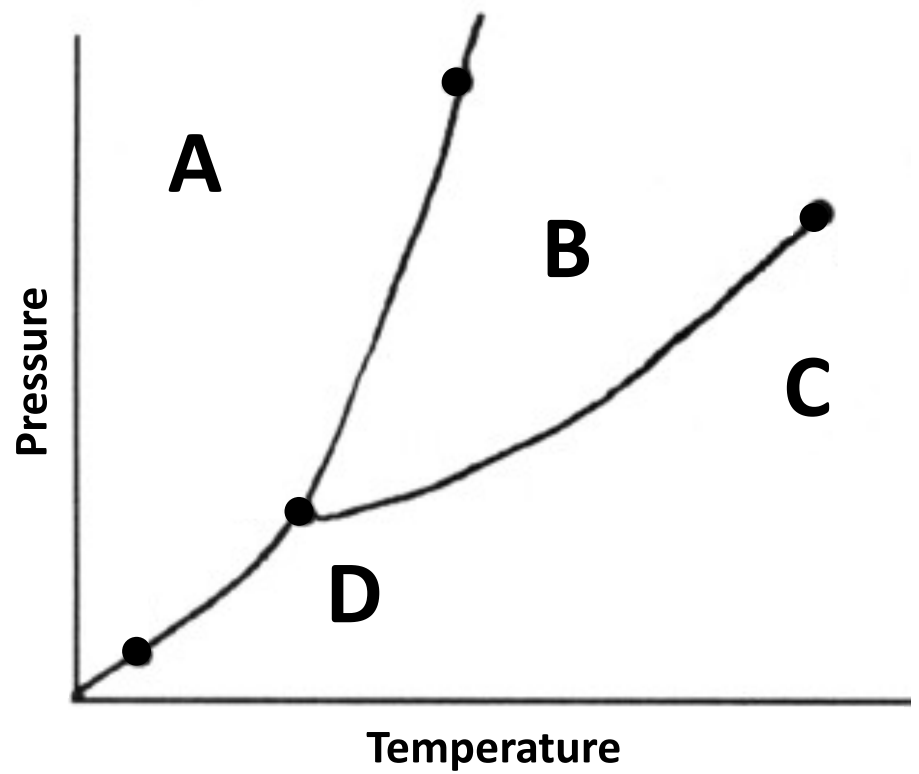
The boiling point of water is about 200°C higher than one would predict from the boiling points of hydrogen sulfide and hydrogen selenide. One may explain this apparent anomaly by which of the following?

A. The H-O covalent bond is much stronger than the H-S and H-Se bonds
B. Water has the lowest molecular weight
C. The intermolecular attractive forces are much greater in water than in hydrogen sulfide and hydrogen selenide. Hydrogen bonding!
D. Water is less polar than hydrogen sulfide and hydrogen selenide.

T16Q16: Level 1 (L.G. 3)

Which region on the phase diagram below corresponds to the solid phase?

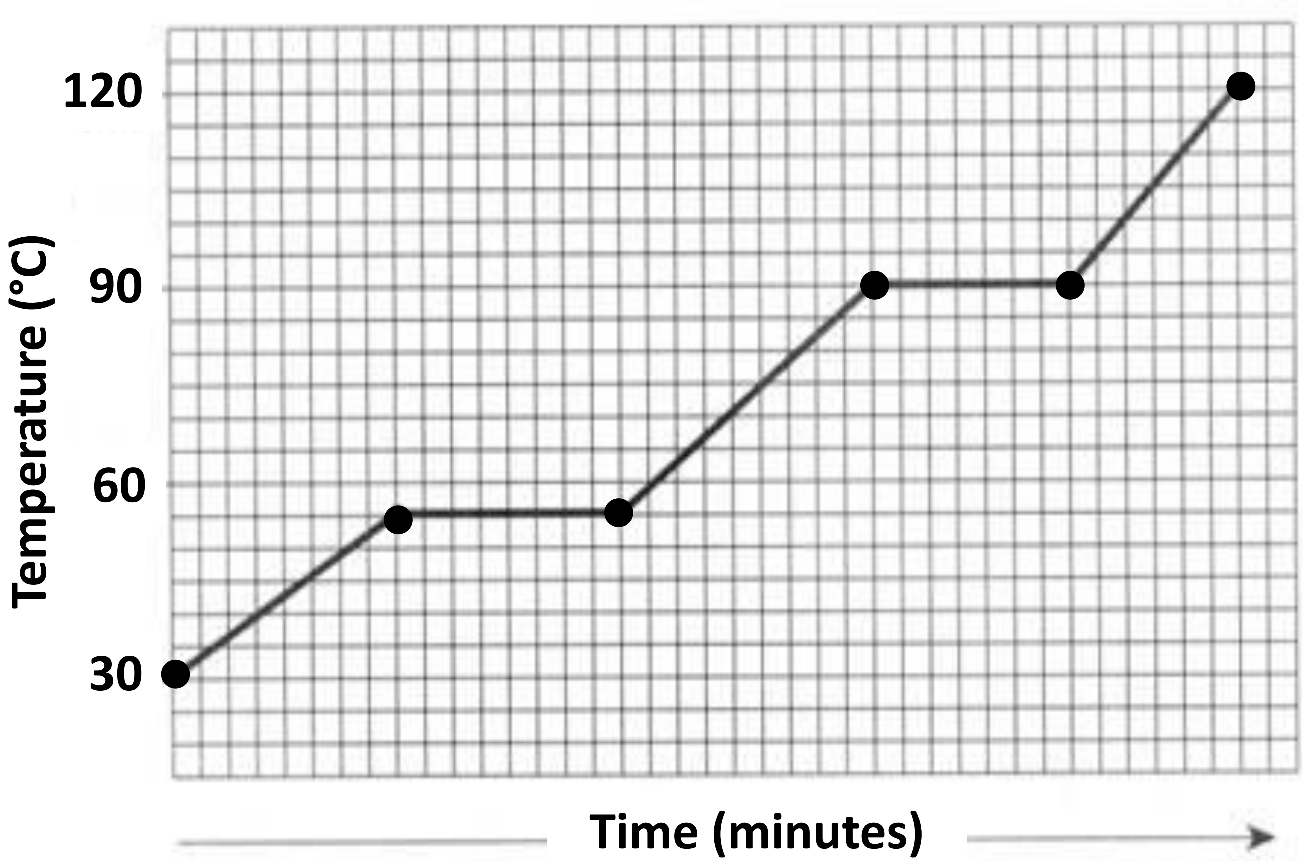
A. A
B. B
C. C
D. D



T16Q17: Level 1 (L.G. 3)

Consider the heating curve below for substance X. At 75°C substance X exists as a _________________.

A. Solid
B. liquid
C. gas
D. liquid and solid
E. liquid and gas

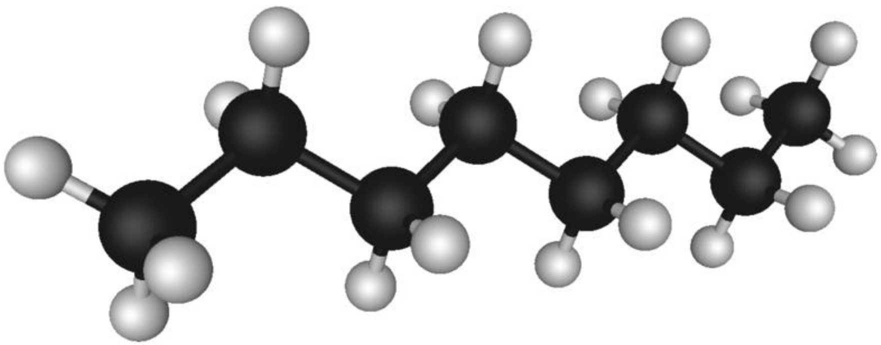


8 pt Challenge

Octane (C_8H_{18}) is a straight chain of carbon atoms with no dipole moment and a boiling point of 125°C. Water has a dipole moment, can hydrogen bond and has a boiling point of 100°C. The difference between these two boiling points can best be rationalized by:

A. **Intermolecular forces between molecules with dipole moments are greater than between molecules with no dipole moment**
B. **Hydrogen bonding is a strong intermolecular force**
C. **London dispersion forces are weak but there are many LDFs in octane so the net IMF in C_8H_{18} is greater than the net IMF in H_2O**
D. **London dispersion forces are strong and so the boiling point of octane is greater than the boiling point of water**
E. **There is no trend, this is a magical mystery of science**

Q0: Solution



of carbon atoms with no dipole
25°C. Water has a dipole moment,
ling point of 100°C. The difference
s can best be rationalized by:

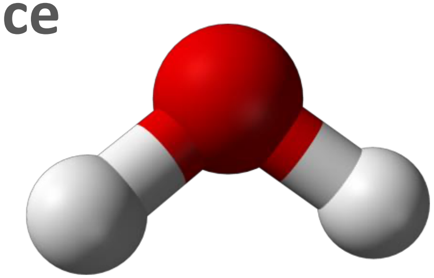
A. Intermolecular forces between molecules with dipole moments are greater than between molecules with no dipole moment

B. Hydrogen bonding is a strong intermolecular force

C. London dispersion forces are weak but there are many LDFs in octane so the net IMF in C_8H_{18} is greater than the net IMF in H_2O

D. London dispersion forces are strong and so the boiling point of octane is greater than the boiling point of water

E. There is no trend, this is a magical mystery of science



T17Q1: Level 2 (L.G. 9)

Calculate the volume of helium in a 2-mole helium balloon that floats up into the atmosphere and is left inflated to a total pressure of 1.5 atm at a temperature of -73 deg C.

A. **37.9 L**
B. **22.1 L**
C. **7.98 L**
D. **0.045 L**

T17Q1: Solution

Calculate the volume of helium in a 2-mole helium balloon that floats up into the atmosphere and is left inflated to a total pressure of 1.5 atm at a temperature of -73 deg C.

A. 37.9 L

B. 22.1 L

C. 7.98 L

D. 0.045 L

SINGLE STATE PROBLEM

$PV = nRT$

T: Kelvin

P: atm

R = 0.082 L-atm/mol-K

$$V = nRT/P = \frac{2.0\ \text{mol} \times (0.082\ \text{L-atm/mol-K}) \times (-73 + 273)\text{K}}{1.5\ \text{atm}}$$

$$= 22.1\ \text{L}$$

T17Q2: Level 2 (L.G. 1)

At what values of temperature and pressure would real gases behave more like ideal gases?

A. **Low pressure and low temperature**
B. **High pressure and high temperature**
C. **Low pressure and high temperature**
D. **High pressure and low temperature**

T17Q2: Solution

SINGLE STATE PROBLEM CHEM RXN

How many moles of nitrogen will be needed to react with 1.5 L of H_2 gas measured at 20°C and 0.95 atm?

A. **0.059 moles**
B. **0.020 moles**
C. **0.18 moles**
D. **0.87 moles**

$$3H_2(g) + N_2(g) \rightarrow 2NH_3(g)$$

PV = nRT

Find moles of H_2 first

$$n = PV/RT$$

$$= \frac{(0.95\text{atm})(1.5\text{ L})}{(0.082\text{ L-atm/mol-K})(20 + 273)\text{K}}$$

$$= 0.059 \text{ moles } H_2$$

$$0.059 \text{ mol } H_2 \times (1 \text{ mol } N_2 / 3 \text{ mol } H_2) = 0.020 \text{ moles } N_2$$

T17Q3: Level 3 (L.G. 9)

What volume of O_2 is needed to completely react with 28.0 g NH_3 at 24°C and 0.950 atm to form NO and water?

A. **4.26 L**
B. **42.3 L**
C. **46.1 L**
D. **52.8 L**

T17Q3: Solution

SINGLE STATE PROBLEM
CHEM RXN

What volume of O_2 is needed to completely react with 28.0 g NH_3 at 24°C and 0.950 atm to form NO and water?

A. 4.26 L
B. 42.3 L
C. 46.1 L
D. 52.8 L

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$$

Find moles of O_2 using Stoich calcs first

28 g x (1 mol/(17 g/mol) = 1.65 moles NH_3

1.65 moles NH_3 x (5 mol O_2/4 mol NH_3)
= 2.06 moles O_2

Now find volume of O_2

PV = nRT

V = nRT/P
= (2.06 moles)(0.082 L-atm/mol-K)(24 + 273 K)/0.95 atm
= 52.8 L

T17Q4: Level 3 (L.G. 11)

Determine the molecular weight of a gas that has a density of 5.75 g/L at STP.

A. **3.90 g/mol**
B. **129 g/mol**
C. **141 g/mol**
D. **578 g/mol**

T17Q4: Solution

SINGLE STATE Molecular Weight

Determine the molecular weight of a gas that has a density of 5.75 g/L at STP.

STP: 1atm, 273K

A. 3.90 g/mol
B. 129 g/mol
C. 141 g/mol
D. 578 g/mol

$$PV = nRT$$

$$n = m/M_w$$

$$PV = RT(m/M_w)$$

$$M_w = RTm/PV$$

$$M_w = (RT/P)\boxed{(m/V)}$$

Density = mass/Vol

$$M_w = [(RT)/P](\text{Density})$$

$$M_w = [(0.082\ \text{L-atm/mol-K})(273\ \text{K})/(1\ \text{atm})](5.75\ \text{g/L})$$

$$= 129\ \text{g/mol}$$

T17Q5: Level 3 (L.G. 11)

Determine the density of a sample of unknown gas with a molar mass of 129 g/mol at STP.

A. **0.174 g/L**
B. **5.76 g/L**
C. **8.64 g/L**
D. **576 g/L**

T17Q5: Solution

Determine the density of a sample of unknown gas with a molar mass of 129 g/mol at STP.

A. 0.174 g/L
B. 5.76 g/L
C. 8.64 g/L
D. 576 g/L

STP: 1atm, 273K

$$PV = nRT$$

$$n = m/M_w$$

$$PV = RT(m/M_w)$$

Density = mass/Vol

$$P = (RT/M_w)\boxed{(m/V)}$$

$$P = (RT/M_w)(\text{density})$$

$$\text{Density} = PM_w/RT$$

$$\text{Density} = (1)(129)/(0.082)(273)$$

$$= 5.76\text{ g/L}$$

T17Q6: Level 2 (L.G. 10)

Consider a sealed sample of gas at 33.0°C, 744 mm Hg, and 450 mL. If the pressure is decreased to 725 mm Hg and the temperature is raised to 66.0°C, what is the new volume of the gas?

A. **512 mL**
B. **124 mL**
C. **417 mL**
D. **483 mL**

CHANGE in the conditions: Double State Problem

T17Q6: Solution

Consider a sealed sample of gas at 33.0°C, 744 mm Hg, and 450 mL. If the pressure is decreased to 725 mm Hg and the temperature is raised to 66.0°C, what is the new volume of the gas?

A. 512 mL
B. 124 mL
C. 417 mL
D. 483 mL

DOUBLE STATE PROBLEM

PV = nRT

R is a constant so it is not included!

T must be in Kelvin

$$\frac{P_iV_i}{\cancel{n_i}T_i}$$

$$V_f = [(P_iV_i)/(P_f)] \times (T_f/T_i)$$

$$= [(744)(450)/(725)] \times [(273+66)/(273+33)]$$

$$= 511.58 \text{ mL}$$

Units cancel so can keep mm Hg. T must be in K!!

T17Q7: Level 3 (L.G. 10)

A 1.9 mol sample of gas in a rigid flask at 21°C and 697 mm Hg is opened to the atmosphere and more gas is added to the flask. The pressure after the addition of gas is 795 mm Hg and the temperature is 26°C. How many moles of gas have been added to the container?

A. **0.23**
B. **1.63**
C. **1.75**
D. **2.13**
E. **2.9**

T17Q7: Solution

A 1.9 mol sample of gas in a rigid flask at 21°C and 697 mm Hg is opened to the atmosphere and more gas is added to the flask. The pressure after the addition of gas is 795 mm Hg and the temperature is 26°C. How many moles of gas have been added to the container?

A. 0.23
B. 1.63
C. 1.75
D. 2.13
E. 2.9

$$\frac{P_i \cancel{V_i}}{P_f \cancel{V_f}} = \frac{n_i T_i}{n_f T_f}$$

DOUBLE STATE PROBLEM

$$n_f = [(n_i T_i)/(T_f)] \times (P_f/P_i)$$

$$= [(1.9)(21+273)/(26+273)] \times [(795)/(697)]$$

$$= 2.13 \text{ moles at the end}$$

Moles added = n_f - n_i = 2.13 - 1.9 = 0.23 moles

T17Q8: Level 3 (L.G. 9)

Which of the following samples contains molecules with the greatest average kinetic energy?

A. **1.0 moles of N_2 at 580 K**
B. **1.0 moles of CO at 140 K**
C. **1.0 moles of N_2O at 298 K**
D. **1.0 moles of CO_2 at 440 K**

T17Q8: Solution

Which of the following samples contains molecules with the greatest average kinetic energy?

A. 1.0 moles of N_2 at 580 K
B. 1.0 moles of CO at 140 K
C. 1.0 moles of N_2O at 298 K
D. 1.0 moles of CO_2 at 440 K

KE is based only on the temperature of the gas
The higher the T the higher the KE

T17Q9: Level 1 (L.G. 15)

Consider 1L gaseous samples of He (4amu), Ne (20amu), and Ar (40amu). If each sample is at STP (273K, 1 atm). Which gas will have the highest molar kinetic energy?

A. **He**
B. **Ne**
C. **Ar**
D. **They all have the same energy**

T17Q9: Solution

Consider 1L gaseous samples of He (4amu), Ne (20amu), and Ar (40amu). If each sample is at STP (273K, 1 atm). Which gas will have the highest molar kinetic energy?

A. He
B. Ne
C. Ar
D. They all have the same energy

KE = 3/2RT

The KE of a gas = the **internal energy** of the system

All at the same temperature so all have the same KE

T17Q10: Level 3 (L.G. 14)

If the temperature of a gas is raised from 100 °C to 200 °C, the average kinetic energy of the gas will ____.

A. **increase by a factor of 2**
B. **increase by a factor of 1.27**
C. **increase by a factor of 100**
D. **decrease by a factor of 2**
E. **decrease by a factor of 100**

T17Q10: Solution

If the temperature of a gas is raised from 100 °C to 200 °C, the average kinetic energy of the gas will ____.

A. increase by a factor of 2
B. increase by a factor of 1.27
C. increase by a factor of 100
D. decrease by a factor of 2
E. decrease by a factor of 100

KE = 3/2RT

R is a constant
3/2 is a constant

DOUBLE STATE PROBLEM

$$\frac{KE_i}{KE_f} = \frac{T_i}{T_f}$$

$$KE_f = KE_i \boxed{(T_f/T_i)}$$

FACTOR

$$(T_f/T_i) = (473)/(373) = 1.27$$

T increases so KE increases

8 pt Challenge again

Consider a rigid tank containing both HF and HBr gases. If this tank develops a leak, what is the ratio of the rate of effusion of HF to the rate of effusion of HBr at constant T?

A. **4.04**
B. **0.247**
C. **2.01**
D. **0.497**

Q0: Solution

Consider the following gas reaction that runs with 100% yield:

1 $2CO(g) + O_2(g) \rightarrow 2CO_2(g)$

How many liters of oxygen gas do you need to completely react with 54 L of carbon monoxide gas at STP?

A. 22 L

$\boxed{\textbf{B.}\ 27\ \text{L}}$

C. 54 L

D. 81 L

E. 108 L

2 PV = nRT

n = PV/RT

= 1 atm(54 L)/(0.082(273K))

= 2.41 moles

3 2.41 moles CO x (1 mol O_2/2 mol CO)

= 1.21 moles O_2

4 PV = nRT

V = nRT/P

= 1.21 moles(0.082)(273K)/1 atm

= 27 L

T18Q1: Level 2 (L.G. 9)

Give the **complete ionic equation** for the reaction that occurs when aqueous solutions of lithium sulfide and copper (II) nitrate are mixed:

A. $Li^{+}(aq) + SO_4^{2-}(aq) + Cu^{+}(aq) + NO_3^{-}(aq)$
$\rightarrow CuS(s) + Li^{+}(aq) + NO_3(aq)$

B. $Li^{+}(aq) + S^{-}(aq) + Cu^{+}(aq) + NO_3^{-}(aq)$
$\rightarrow CuS(s) + LiNO_3(aq)$

C. $2Li^{+}(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^{-}(aq)$
$\rightarrow Cu^{2+}(aq) + S^{2-}(aq) + 2LiNO_3(s)$

D. $2Li^{+}(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^{-}(aq)$
$\rightarrow CuS(s) + 2Li^{+}(aq) + 2NO_3^{-}(aq)$

T18Q1: Solution

Give the **complete ionic equation** for the reaction that occurs when aqueous solutions of lithium sulfide and copper (II) nitrate are mixed:

A. $Li^{+}(aq) + SO_4^{2-}(aq) + Cu^{+}(aq) + NO_3^{-}(aq)$
$\rightarrow CuS(s) + Li^{+}(aq) + NO_3(aq)$

B. $Li^{+}(aq) + S^{-}(aq) + Cu^{+}(aq) + NO_3^{-}(aq)$
$\rightarrow CuS(s) + LiNO_3(aq)$

C. $2Li^{+}(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^{-}(aq)$
$\rightarrow Cu^{2+}(aq) + S^{2-}(aq) + 2LiNO_3(s)$

D. $2Li^{+}(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^{-}(aq)$
$\rightarrow CuS(s) + 2Li^{+}(aq) + 2NO_3^{-}(aq)$

Complete Ionic Equation:
contains the solids and ALL the ionic species

T18Q2: Level 2 (L.G. 9)

Give the **net ionic equation** for the reaction that occurs when aqueous solutions of barium nitrate and ammonium phosphate are mixed:

A. $3Ba(NO_3)_2(aq) + 2(NH_4)_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NH_4NO_3(aq)$

B. $3Ba(NO_3)_2(aq) + 2(NH_4)_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(aq) + 6NH_4NO_3(s)$

C. $2NO_3^-(aq) + 6NH_4^+(aq) \rightarrow 6NH_4NO_3(s)$

D. $3Ba^{2+}(aq) + 2PO_4^-(aq) \rightarrow Ba_3(PO_4)_2(s)$

E. $2NO_3^-(aq) + 6NH_4^+(aq) + 2PO_4^-(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NH_4^+(aq) + NO_3^-(aq)$

T18Q2: Solution

Give the **net ionic equation** for the reaction that occurs when aqueous solutions of barium nitrate and ammonium phosphate are mixed:

A. $3Ba(NO_3)_2(aq) + 2(NH_4)_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NH_4NO_3(aq)$

B. $3Ba(NO_3)_2(aq) + 2(NH_4)_3PO_4(aq) \rightarrow Ba_3(PO_4)_2(aq) + 6NH_4NO_3(s)$

C. $2NO_3^-(aq) + 6NH_4^+(aq) \rightarrow 6NH_4NO_3(s)$

D. $\boxed{3Ba^{2+}(aq) + 2PO_4^-(aq) \rightarrow Ba_3(PO_4)_2(s)}$

E. $2NO_3^-(aq) + 6NH_4^+(aq) + 2PO_4^-(aq) \rightarrow Ba_3(PO_4)_2(s) + 6NH_4^+(aq) + NO_3^-(aq)$

Net Ionic Equation:

Only the species that ACTUALLY react to form a solid!

All NH_4^+ and NO_3^- ion salts are soluble so any species with those ions will cancel out

T18Q3: Level 3 (L.G. 10)

Consider the decomposition of calcium carbonate to form calcium oxide and carbon dioxide. If the reaction produced 732 mL of CO_2 at 21°C and 77.1 cm Hg, how many grams of CaO are produced?

A. **0.21 g**
B. **1.73 g**
C. **1.86 g**
D. **3.10 g**
E. **17.2 g**

T18Q3: Solution

Consider the decomposition of calcium carbonate to form calcium oxide and carbon dioxide. If the reaction produced 732 mL of CO_2 at 21°C and 77.1 cm Hg, how many grams of CaO are produced?

A. 0.21 g
B. 1.73 g
C. 1.86 g
D. 3.10 g
E. 17.2 g

1 $CaCO_3(s) \rightarrow CaO(s) + CO_2(g)$

77.1 cm Hg = 1.01 atm
21°C = 294 K

2 **PV = nRT**

n = PV/RT
= (1.01 atm)(0.732L)/(0.082 L-atm/mol-K)(294 K)
= 0.031 moles

3 1:1 mole ratio
0.031 moles CaO

4 0.031 moles CaO x 56.08 g/mol
= 1.73 grams

T18Q4: Level 3 (L.G. 10)

Consider the reaction between 100 mL of 0.41 M iron(II) nitrate with 63 mL of 0.35M potassium phosphate. How many moles of precipitate are formed from this reaction?

A. **0.011**
B. **0.014**
C. **0.022**
D. **0.041**

T18Q4: Solution

Consider the reaction between 100 mL of 0.41 M iron(II) nitrate with 63 mL of 0.35M potassium phosphate. How many moles of precipitate are formed from this reaction?

1 $3Fe(NO_3)_2(aq) + 2K_3PO_4(aq) \rightarrow 6KNO_3(aq) + Fe_3(PO_4)_2(s)$

A. 0.011
B. 0.014
C. 0.022
D. 0.041

2 $M = \frac{\text{moles of solute}}{\text{volume of solution (L)}}$ moles = M x vol (L)

	$3Fe(NO_3)_2$	$2K_3PO_4$
	0.41 M x 0.100 L = 0.041 mol	0.35 M x 0.063 L = 0.0221 mol
3 LR calcs	0.041 x (1/3) = 0.014 mol $Fe_3(PO_4)_2$	0.0221 x (1/2) = 0.011 mol $Fe_3(PO_4)_2$

T18Q5: Level 3 (L.G. 10)

What mass, in g, of AgCl is formed from the reaction of 75.0 mL of a 0.078 M $AgC_2H_3O_2$ solution with 55.0 mL of 0.109 M $MgCl_2$ solution?

A. **0.860 g**
B. **1.72 g**
C. **2.56 g**
D. **3.20 g**

T18Q5: Solution

What mass, in g, of AgCl is formed from the reaction of 75.0 mL of a 0.078 M $AgC_2H_3O_2$ solution with 55.0 mL of 0.109 M $MgCl_2$ solution?

1 $2AgC_2H_3O_2(aq) + MgCl_2(aq) \rightarrow 2AgCl(s) + Mg(C_2H_3O_2)_2(aq)$

A. 0.860 g
B. 1.72 g
C. 2.56 g
D. 3.20 g

2 $M = \frac{\text{moles of solute}}{\text{volume of solution (L)}}$ moles = M x vol (L)

	$AgC_2H_3O_2$	$MgCl_2$
	0.078 M x 0.075 L = 0.006 mol	0.109 M x 0.055 L = 0.0060 mol
LR calcs 3	0.006 x (2/2) = 0.006 mol AgCl	0.006 x (2/1) = 0.012 mol AgCl
4	0.006 mol x (143.35 g / 1 mol) = 0.86 g	

T18Q6: Level 2 (L.G. 8)

What precipitate is most likely formed from a solution containing Ba^{+2}, Na^{+1}, OH^{-1}, and CO_3^{-2}?

A. **$NaOH$**
B. **$BaCO_3$**
C. **Na_2CO_3**
D. **$Ba(OH)_2$**

T18Q6: Solution

What precipitate is most likely formed from a solution containing Ba^{+2}, Na^{+1}, OH^{-1}, and CO_3^{-2}?

A. NaOH → **Soluble, bc Na is a group 1 metal**

B. $\boxed{BaCO_3}$

C. Na_2CO_3 → **Soluble, bc Na is a group 1 metal**

D. $Ba(OH)_2$ → **Slightly soluble, bc OH & Ba^{2+}**

2. **Alkali metal (Group 1A) salts and NH_4^+ are soluble.**

3. **F^-, S^{2-}, CO_3^{2-}, CrO_4^{2-}, PO_4^{3-} salts are insoluble, except for those containing Group 1A cations.**

6. **OH salts are insoluble (except for those containing Group 1A cations and NH_4^+ which are soluble and those containing Ca^{2+}, Sr^{2+} and Ba^{2+} which are slightly soluble).**

T18Q7: Level 3 (L.G. 8)

How many of the following compounds are **soluble** in water?

$Cu(OH)_2$ $LiNO_3$ NH_4Br K_2SO_4 $PbCl_2$ $BaSO_4$

A. 0
B. 1
C. 2
D. 3
E. 4

T18Q7: Solution

How many of the following compounds are **soluble** in water?

$Cu(OH)_2$ $\boxed{LiNO_3}$ $\boxed{NH_4Br}$ $\boxed{K_2SO_4}$ $PbCl_2$ $BaSO_4$

Soluble Soluble Soluble

A. 0
B. 1
C. 2
D. 3
E. 4

1. Nitrate (NO_3^{-1}) and acetate ($C_2H_3O_2^{-1}$) salts are soluble.
2. Alkali metal (Group 1A) salts and NH_4^+ are soluble.
4. Cl^{-1}, Br^{-1}, and I^{-1} salts are soluble (except when combined with Ag^+, Hg_2^{2+}, Pb^{2+}).
5. Sulfate salts are soluble (except when combined with Ag^+, Hg_2^{2+}, Pb^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+}).
6. OH^{-1} salts are insoluble (except for those containing Group 1A cations and NH_4^+ which are soluble and those containing Ca^{2+}, Sr^{2+} and Ba^{2+} which are slightly soluble).

T18Q8: Level 1 (L.G. 6)

Choose the reaction that represents a combustion reaction:

A. $C_6H_{12}O_2(l) + 8O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$
B. $Mg(s) + Cl_2(l) \rightarrow MgCl_2(aq)$
C. $C_6H_{12}O_2(l) \rightarrow 6C(s) + 6H_2(g) + O_2(g)$
D. $NaOH(aq) + CuCl_2(aq) \rightarrow NaCl_2(aq) + Cu(OH)_2(s)$
E. None of the above are combustion

T18Q8: Solution

Choose the reaction that represents a combustion reaction:

A. $C_6H_{12}O_2(l) + 8O_2(g) \rightarrow 6CO_2(g) + 6H_2O(g)$
B. $Mg(s) + Cl_2(l) \rightarrow MgCl_2(aq)$
C. $C_6H_{12}O_2(l) \rightarrow 6C(s) + 6H_2(g) + O_2(g)$
D. $NaOH(aq) + CuCl_2(aq) \rightarrow NaCl_2(aq) + Cu(OH)_2(s)$
E. None of the above are combustion

A = Combustion (reaction with oxygen)

B = Synthesis (combining things)

C = Decomposition (breaking down)

D = Double displacement (swapping ions)

T18Q9: Level 2 (L.G. 9)

Give the **complete ionic equation** for the reaction that occurs when aqueous solutions of lithium sulfide and copper (II) nitrate are mixed:

A. $Li^{+}(aq) + SO_4^{2-}(aq) + Cu^{+}(aq) + NO_3^{-}(aq)$
$\rightarrow CuS(s) + Li^{+}(aq) + NO_3(aq)$

B. $Li^{+}(aq) + S^{-}(aq) + Cu^{+}(aq) + NO_3^{-}(aq)$
$\rightarrow CuS(s) + LiNO_3(aq)$

C. $2Li^{+}(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^{-}(aq)$
$\rightarrow Cu^{2+}(aq) + S^{2-}(aq) + 2LiNO_3(s)$

D. $2Li^{+}(aq) + S^{2-}(aq) + Cu^{2+}(aq) + 2NO_3^{-}(aq)$
$\rightarrow CuS(s) + 2Li^{+}(aq) + 2NO_3^{-}(aq)$