$N_A = 6.02 \times 10^{23}$ particles/mol

Part A: Knowledge & Understanding

1. Multiple choice (10 marks): Please answer all questions on your scantron card in pencil.

2. ~~Explain how~~ the Avogadro constant, average atomic mass, and molar mass are related. ~~Use examples to explain your answer.~~ (3 marks K)

Avogadro's constant is the number of particl
for each mol it is essentially a definition of a mol.
Average atomic mass is the number of grams per
mol of a element, molar mass is equivalent to
atomic mass but also covers compounds. If someon
were to ring the number of particles in 1g of H_2O
they would have to add up the average atomic masses to create
a molar mass divide mass
by molar mass and multiply

2K

Part B: Thinking and Investigation & Communication

3. What mass of pure silver is contained in 2.00×10^2 g of silver nitrate, $AgNO_{3(s)}$? (3 marks T, 1 mark C)

200g $AgNO_3$

$= \frac{200g}{(107.87+14+3\times16)g/mol}$

$= 1.18\ mol\ AgNO_3 \times 1$

$= 1.18\ mol\ Ag \times 107.87\ g/mol = 127.3\ g\ Ag$

So There is 127g of silver in silver nitrate

3T+1C

4. A class of compounds called sodium metaphosphates were used as additives to detergents to improve cleaning ability. One of them has a molar mass of 612g/mol. Analysis shows the composition to be 22.5% Na, 30.4% P, and 47.1% O.

a) Determine the empirical formula of the compound. (3 marks T, 1 mark C)

22.5 mol Na | 30.4 mol P | 47.1 mol O

÷ 1 | ÷ 1.55 | ÷ 2.09

× 3 | × 3

= 3 | 4 | 6

$= Na_3P_4O_6$

b) Determine the molecular formula of this compound. (2 marks T, 1 mark C)

$MM = (22.99\times3 + 4\times30.97 + 6\times16.00)$

$= 288.85\ g/mol$

$\text{Multiplier} = \frac{612\ g/mol}{288.85\ g/mol} = 2.13x = 2x$

$= Na_6P_8O_{12}$

1T + ½C

4T + 1SC

the substance is sodium, this is solved with basic math if oxygen is 25.8% then the formula is $25.8\% = \frac{16\text{g/mol}}{2x+16\text{g/mol}}$ then solve for x, x = the mole

$25.8\% = \frac{16\text{g/mol}}{2x+16\text{g/mol}} \times 100$

$\frac{16}{0.258} = 2x+16$

$62 = 2x+16 \quad x = \frac{62-16}{2} = 23\text{g/mol}$

3T+1C

mass of substance

6. An impure sample of barium chloride, $BaCl_2$, with a mass of 4.36 g, is added to an aqueous solution of sodium sulfate, Na_2SO_4. This results in the formation of a precipitate of barium sulfate, $BaSO_{4(s)}$.

$$BaCl_{2(s)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$$

4.36g 2.62g

After the reaction is complete, the solid barium sulfate, $BaSO_4$, is filtered and dried. Its mass is found to be 2.62 g. Calculate what mass of barium chloride was contained in the original (impure) sample? (4 marks T, 1 mark C)

4.36

$\frac{2.62\text{g}}{233.40\text{g/mol}}$ $BaSO_4$

$= 0.0112\text{mol}$ $BaSO_4$

1 : 1

$= 0.0112\text{mol}$ $BaCl_2$

$\times 208.23\text{g/mol}$

$= 2.33\text{g}$ of $BaCl_2$

4.36g of impure $BaCl_2$ − 2.33g theoretical amount

$= 1.87\text{g}$ $BaCl_2$ x

3T+½C

So There was 1.87g $BaCl_2$ out of the impure substance.

6T+1.5C

7. 7.50 g of benzene, C_6H_6 reacts with 16.75 Br_2 to form bromobenzene, C_6H_5Br. ($C_6H_{6(g)} + Br_2(g) \rightarrow C_6H_5Br_{(g)} + HBr_{(g)}$)

a) What is the limiting reactant? (3 marks T, 1 mark C)

7.5g C_6H_6 + 16.75g Br_2

78.12g/mol 159.8g/mol

0.096 mol : 0.105 mol

0.096 0.096

1 : 1.0937 5

∴ There is an excess of Bromine ∴ the limiting reactant is benzene

3T+1C ✓

b) What mass of bromobenzene, is produced? (2 marks T, 1 mark C)

0.096 mol of each ~~substance~~ reactant is used

0.096 mol of bromobenzene

0.096 mol × 157.01 g/mol = 15.1 g

2T+1C

∴ The mass of bromobenzene is 15.1 g ✓

c) What is the mass of the unused excess reactant?(2 marks T, 1 mark C)

Δ excess = 0.105 mol − 0.096 mol = 0.009 mol Br

0.009 mol · 159.8 g/mol = 1.4 g

2T+½C

∴ There is 1.4g of excess Bromine

8. The following reaction proceeds with a 92.4% yield. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

How many grams of calcium oxide can the chemist expect to obtain if 12.4 g of calcium carbonate is heated? (3 marks T, 1 mark C)

12.4g $CaCO_3$

100.09 g/mol

= 0.1239 mol $CaCO_3$

× 92.4%

= 0.1145 mol $CaCO_3$ × 1

1 : 1

= 0.1145 mol CaO

3T+1C

∴ The chemist can expect 6.41g of CaO with a 92.4% yield ✓

5. A compound contains an unknown element X. This element forms an oxide with chemical formula X_2O. Experimental tests show that X_2O contains 25.8 % oxygen, by mass. What is the identity of element X? Explain. (3 marks T, 1 mark C)

Na_2O

+2 -> -2

X_2O

25.8% O

25.8mol 25.8mol

$25.8\% = \frac{16 g/mol}{2x + 16 g/mol} \times 100$

$\frac{16}{0.258} = 2x + 16$

$62 = 2x + 16$

$x = \frac{62 - 16}{2}$

$= 23 g/mol$

So The identity of the substance is sodium, this is solved with basic math if Oxygen is 25.8% then the formula is $25.8\% = \frac{16 g/mol}{2x + 16 g/mol}$ It's on solve for x, x = the molar mass of substance which is 23 g/mol

3T + 1C

6. An impure sample of barium chloride, $BaCl_2$, with a mass of 4.36 g, is added to an aqueous solution of sodium sulfate, Na_2SO_4. This results in the formation of a precipitate of barium sulfate, $BaSO_{4(s)}$.

$$BaCl_{2(s)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4(s)} + 2NaCl_{(aq)}$$

4.36 g 2.62 g

After the reaction is complete, the solid barium sulfate, $BaSO_4$, is filtered and dried. Its mass is found to be 2.62 g. Calculate what mass of barium chloride was contained in the original (impure) sample? (4 marks T, 1 mark C)

4.36

$\frac{2.62 g}{233.40 g/mol}$ $BaSO_4$

= 0.0112 mol $BaSO_4$

1 : 1

= 0.0112 mol $BaCl_2$

× 208.23 g/mol

= 2.33 g of $BaCl_2$

4.36 g of impure $BaCl_2$ − 2.33 g theoretical amount

= ~~1.87 g $BaCl_2$~~

3T + ½C

So There was 1.87 g $BaCl_2$ out of the impure substance.

7. 7.50 g of benzene, C_6H_6 reacts with 16.75 Br_2 to form bromobenzene, C_6H_5Br. ($C_6H_{6(g)} + Br_2(g) \rightarrow C_6H_5Br_{(g)} + HBr_{(g)}$)

a) What is the limiting reactant? (3 marks T, 1 mark C)

$\frac{7.5g\ C_6H_6}{78.12g/mol} + \frac{16.75g\ Br_2}{159.8g/mol}$

$0.096mol : 0.105mol$

$\frac{0.096}{0.096} : \frac{0.105}{0.096}$

$1 : 1.09375$

∴ There is an excess of Bromine ∴ the limiting reactor is benzene

3T+1C

b) What mass of bromobenzene, is produced? (2 marks T, 1 mark C)

0.096 mol of each ~~substance~~ reactant is used

0.096 mol of bromobenzene

$0.096mol \times 157.01g/mol = 15.1g$

2T+1C

∴ The mass of bromobenzene is 15.1g ✓

c) What is the mass of the unused excess reactant?(2 marks T, 1 mark C)

$\Delta excess = 0.105mol - 0.096mol = 0.009mol\ Br$

$0.009mol \cdot 156.89g/mol = 1.4g$

2T+½C

∴ There is 1.4g of excess Bromine

8. The following reaction proceeds with a 92.4% yield. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

How many grams of calcium oxide can the chemist expect to obtain if 12.4 g of calcium carbonate is heated? (3 marks T, 1 mark C)

$12.4g\ CaCO_3$

$100.09g/mol$

$= 0.1239mol\ CaCO_3$

$\times 92.4\%$

$= 0.1145mol\ CaCO_3 \times 1$

1 : 1

$= 0.1145mol\ CaO$

$\times 56.04g/mol\ CaO$

∴ The chemist can expect 6.41g of CaO with a 92.4% yield ✓

3T+1C

10T+3.5C

Part C: Application

9. Gold can be extracted from ore containing gold(III) sulfide by passing hydrogen gas through the ore: $Au_2S_{3(s)} + 3H_{2(g)} \rightarrow 3H_2S_{(g)} + 2Au_{(s)}$
Based on the chemical equation, which reagent should be the limiting reagent in order for this process to be most profitable? Justify your choice. (3 marks A)

For this reaction gold(III) sulfide should be the limiting reactant, hydrogen is extremely abundant and cheap so having excess of it is not a problem however gold(III) sulfide is expensive so it should be used up to its fullest in the reaction ✓ 3A

10. There are a number of fossil fuels that are burned for energy consumption. Hydrogen has also been proposed as a fuel for automobiles and, unlike fossil fuels, it produces only water. For the reactions listed below:

$2H_{2(g)} + O_{2(g)} \rightarrow 2H_2O_{(l)} + \text{energy}$
$2C_8H_{18(g)} + 25O_{2(g)} \rightarrow 18H_2O_{(g)} + 16CO_{2(g)} + \text{energy}$
$C_3H_{8(g)} + 5O_{2(g)} \rightarrow 4H_2O_{(g)} + 3CO_{2(g)} + \text{energy}$
$CH_{4(g)} + 2O_{2(g)} \rightarrow 2H_2O_{(g)} + CO_{2(g)} + \text{energy}$

Explain which of the above fuels would be cleaner burning and more environmentally friendly. (3 marks A)

The synthesis of hydrogen and oxygen to create only water is the most efficient. All the other ✓ 3A reactions form carbon dioxide, a harmful greenhouse gas while this reaction forms water. Not only this but it uses simple abundant reactants like hydrogen and oxygen while the others require hydrocarbons which can be damaging to the environment when harvested/mined. Finally water is easy to dispose of compared to ✓

11. Imagine that you are a lawyer. You are representing a client charged with possession of a controlled substance. The prosecutor introduces, as a forensic evidence, the empirical formula of the substance that was found in your client's possession. How would you deal with the evidence as a lawyer for defence? Support your answer with examples. (3 marks A)

I would argue that the prosecutor is misleading the jury, an empirical formula does not fully represent the properties of a compound, the molecular formula must be shown. ✓ 2A
Not only this but just showing a formula is misleading sodium and chlorine are both very dangerous but when combined it makes simple table salt. Methane (NH_3) is a highly dangerous and corrosive