5 marks each

1. The element mercury has seven naturally occurring isotopes. Based on the isotopic masses and abundances shown below, calculate the average atomic mass of mercury.

   Average atomic mass Hg = (.00146 x 195.96580) + (0.1002 x 197.9668) + (0.1684 x 198.9683) + (0.2313 x 199.9683) + (0.1322 x 200.9703) + (0.2980 x 201.9706) + (0.0685 x 203.9735) = 200.6090 amu

Isotope	Mass (amu)	Abundance (%)
^{196}Hg	195.9658	0.146
^{198}Hg	197.9668	10.02
^{199}Hg	198.9683	16.84
^{200}Hg	199.9683	23.13
^{201}Hg	200.9703	13.22
^{202}Hg	201.9706	29.80
^{204}Hg	203.9735	6.85

2. Dieldrin is an insecticide composed of carbon, hydrogen, oxygen, and chlorine. A 2.416 g sample of dieldrin is subjected to combustion analysis, yielding 3.350 g $CO_2$and 0.458 g H_2O. Mass spectrometry gives a molecular weight of 381 g mol^{-1}. From a separate experiment, it is found that there are 2:1 ratio of C:Cl atoms. Based on this information, what is the molecular formula of dieldrin?

   $3.350g\ CO_2 \times \frac{1\ mol\ CO_2}{44.01g\ CO_2} = 0.07612\ mol\ CO_2$

   $0.458g\ H_2O \times \frac{1\ mol\ H_2O}{18.02g\ H_2O} = 0.0254\ mol\ H_2O$

   $0.07612\ mol\ CO_2 : 1\ mol\ C$

   $0.07612\ mol\ C \times \frac{12.01g}{1\ mol\ C} = 0.9412g\ C$

   $0.0254\ mol\ H_2O : 2\ mol\ H$

   $0.0254 \times \frac{1.008g}{1\ mol\ H} \times 2 = 0.05126g\ H$

2 mol C : 1 mol Cl

0.07612 mol C : 0.03806 mol Cl

$0.03806 \text{ mol Cl} \times \frac{35.45\text{g}}{1 \text{ mol Cl}} = 1.349 \text{ g Cl}$

2.416g dieldrin – 0.9412g C – 0.0512g H – 1.349 g Cl = 0.1002g O

$0.1002\text{g O} \times \frac{1 \text{ mol O}}{16.00\text{g}} = 0.006263 \text{ mol O}$

$C_{\frac{0.07612}{0.006263}} H_{\frac{0.0512}{0.006263}} Cl_{\frac{0.03806}{0.006263}} O_{\frac{0.006263}{0.006263}} = C_{12}H_8Cl_6O$

Molar mass: (12 x 12.01) + (8 x 1.002) + (6 x 35.45) + (16.00) = 381 g mol^{-1}

3. An iron sulfide contains 36.5% S by mass. The iron sulfide is heated in an atmosphere of pure oxygen, which produces $SO_{2(g)}$ and an iron oxide containing 27.6% O by mass.

a. Write a balanced equation for the reaction.

In a 100g sample of an iron sulphide: 36.5g S, 100g-36.5g = 63.5g Fe

$36.5\text{g S} \times \frac{1 \text{ mol S}}{32.066\text{g mol}^{-1}} = 1.14 \text{ mol S}$

$63.5\text{g Fe} \times \frac{1 \text{ mol Fe}}{55.847\text{g mol}^{-1}} = 1.14 \text{ mol Fe}$

Iron sulphide is FeS

In a 100g sample of an iron oxide: 27.6g O, 100g-27.6g=72.4g Fe

$27.6\text{g O} \times \frac{1 \text{ mol O}}{15.9994\text{g mol}^{-1}} = 1.73 \text{ mol O}$

$72.4\text{g Fe} \times \frac{1 \text{ mol Fe}}{55.847\text{g mol}^{-1}} = 1.30 \text{ mol Fe}$

$Fe_{\frac{1.3}{1.3}}O_{\frac{1.73}{1.3}} = Fe_1O_{1.3} \times 3 = Fe_3O_4$

unbalanced: $FeS + O_2 = SO_2 + Fe_3O_4$

balanced: $3FeS + 5O_2 = 3SO_2 + Fe_3O_4$

b. If 1.0 kg of the iron sulfide reacts with excess oxygen, what is the theoretical yield of the iron oxide?

Molar mass FeS = 55.847g Fe mol^{-1} + 32.066g S mol^{-1}=87.913g FeS mol^{-1}

1kg=1000g, 1000g/87.913g mol^{-1} =11.375 mol FeS

3 mol FeS : 1 mol Fe_3O_4, 11.375mol : 3.792 mol Fe_3O_4

3.792 mol x (3 x 55.847g + 4 x 15.9994g) = 877.994g Fe_3O_4

The theoretical yield of the iron oxide (Fe_3O_4) from 1kg Iron sulfide is 3.792 mol Fe_3O_4 or 877.994 g Fe_3O_4.

4. In the manufacture of Portland cement, limestone ($CaCO_{3(s)}$) is decomposed into lime ($CaO_{(s)}$) and $CO_{2(g)}$), in a kiln. Use data from Appendix II, part C in your textbook to calculate how much heat is required to decompose 2.70×10^3 kg of limestone. (Assume that the heats of reaction are temperature independent.)

$CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$

$\Delta_rH° = \Sigma\, n_p \Delta_f H° - \Sigma\, n_r \Delta_f H°$

$= (-1207.6 \text{ kJ mol}^{-1}) – (-634.9 \text{ kJ mol}^{-1} + -393.5 \text{ kJ mol}^{-1})$

$= 179.2 \text{ kJ mol}^{-1}$

Molar mass $CaCO_3$ = (40.078g mol^{-1}) + (12.011 g mol^{-1}) + (3 x 15.9994 g mol^{-1})

= 100.09 g mol^{-1}

2.7 x 10^3kg $CaCO_3$ = 2.7 x 10^6 g $CaCO_3$

2.7 x 10^6 g $CaCO_3$/100.09g mol^{-1}=2.70x10^4 mol $CaCO_3$

2.70x10^4 mol $CaCO_3$ x 179.2 kJ mol^{-1} = 4.834 x 10^6 kJ are required to decompose 2.70 x 10^3 kg of limestone.

5. Hydrogen gas can be produced from natural gas, which is primarily composed of methane (CH_4). Determine $\Delta_rH°$ for the following reaction, given the reaction enthalpy data shown in the table below.

$$\mathbf{CH_{4(g)} + \tfrac{1}{2} O_{2(g)} \rightarrow CO_{(g)} + 2H_{2(g)}}$$

$\tfrac{1}{4} CH_{4(g)} + \tfrac{1}{2} O_{2(g)} \rightarrow \cancel{\tfrac{1}{4} CO_{2(g)}} + \cancel{\tfrac{1}{2} H_2O_{(g)}})$ $\Delta_rH° = \tfrac{1}{4} \times -802 \text{ kJ mol}^{-1}$

$\tfrac{1}{4} CH_{4(g)} + \cancel{\tfrac{1}{4} CO_{2(g)}} \rightarrow \tfrac{1}{2} CO_{(g)} + \tfrac{1}{2} H_{2(g)})$ $\Delta_rH° = \tfrac{1}{4} \times 247 \text{ kJ mol}^{-1}$

$\underline{\tfrac{1}{2} CH_{4(g)} + \cancel{\tfrac{1}{2} H_2O_{(g)}} \rightarrow \tfrac{1}{2} CO_{(g)} + 1\tfrac{1}{2} H_{2(g)}}$ $\Delta_rH° = \tfrac{1}{2} \times 206 \text{ kJ mol}^{-1}$

$CH_4 + \tfrac{1}{2} O_2 \rightarrow CO + 2H_2$

	$\Delta_rH°$ (kJ mol^{-1})
$CO_{2(g)} + 2H_2O_{(g)}$	−802
$2CO_{(g)} + 2H_{2(g)}$	+247
$CO_{(g)} + 3H_{2(g)}$	+206

$\Delta_rH° = ¼ \times -802$ kJ mol^{-1}

+ $\Delta_rH° = ¼ \times 247$ kJ mol^{-1}

+ $\Delta_rH° = ½ \times 206$ kJ mol^{-1}

$\Delta_rH° = -35.75$ kJ mol^{-1}

6. A 1.500 L flask is filled with a mixture of 1.20 g H_2 and 8.40 g O_2, at 25°C. The mixture is ignited, and hydrogen and oxygen combine to form water.
   a. What is the total pressure inside the flask before the reaction? (Report your answer in units of atmospheres.)

PV=nRT

Find: P   V=1.500L

T=25°C=298.15K

n= (1.2g x 1mol/1.00794g H) + (8.40g x 1g/15.9994g O)= 1.716 mol gas

R= 0.08314 L bar mol^{-1} K^{-1}

PV=nRT

$P = \frac{(1.716 \text{ mol})(0.08314 \text{ L bar mol}^{-1} \text{ K}^{-1})(298.15 \text{ K})}{1.500\text{L}} = 28.36\text{bar} \times \frac{0.98692\text{atm}}{1 \text{ bar}} = 27.99\text{atm}$

   b. What is the total pressure after the reaction, once the flask is returned to 25°C? (Vapour pressure of water at 25°C is 23.8 mm Hg.)

7. Draw an energy-level diagram that shows all of energy levels from n = 5 to n = 1. Draw all possible *emission* lines between these levels. In your diagram, ensure that the energy levels are spaced correctly (e.g. according to the Bohr model).

8. In the photoelectric effect, the work function is the energy that must be supplied to overcome the attractive forces that hold an electron in the metal. For mercury, the work function is equal to 435 kJ mol^{-1} of photons. What is the kinetic energy, in joules, of the ejected electrons when light with a wavelength of 220 nm strikes the surface of mercury?