

Each of the eight questions will be marked out of 10. You must answer all questions in your exam booklet.

Given Information

$$R = 8.314 \text{ J/(mol K)} \quad 1 \text{ F} = 96,500 \text{ J/(V mol)} \quad 1 \text{ atm} = 101.325 \text{ kPa} = 760 \text{ mmHg}$$

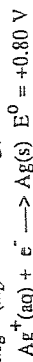
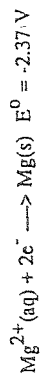
molar masses (g/mol)

N: 14.0, Mg: 24.3

$$\ln \left[\frac{P_2}{P_1} \right] = - \frac{\Delta H_{\text{vap}}}{R} \left[\frac{1}{T_2} - \frac{1}{T_1} \right]$$

$$E = E^0 \cdot \frac{RT}{nF} \ln Q$$

$$\text{At } 25^\circ\text{C} \quad E = E^0 - \frac{0.0591}{n} \log Q$$



1) A piece of magnesium metal weighing 1.56 g is placed in 100.0 mL of 0.100 M AgNO_3 at 25°C .

a) Calculate $[\text{Mg}^{2+}]$ and $[\text{Ag}^+]$ in solution at equilibrium.

b) What mass of magnesium is left? You may assume that the volume remains constant.

2) 1.00 mole of gas containing an unknown mix of methane (CH_4) and propane (C_3H_8) was combined with 5.00 moles of oxygen gas in a 40.0 litre constant volume reactor. The mixture was burned completely to $\text{H}_2\text{O}(\text{g})$ and $\text{CO}_2(\text{g})$. After combustion a total of 6.40 moles of gas were left.

a) What was the molar ratio of methane to propane in the original gas mixture?

b) If the original gas mixture was at 25°C , what was the partial pressure of oxygen in this mixture?

3) An ideal solution consisting of benzene, toluene and p-xylene has a normal boiling point of 100°C . The mole fraction of benzene in the vapour phase is 0.632. Calculate:

a) the mole fraction of benzene in the liquid phase, and

b) the mole fraction of p-xylene in the vapour phase.

Vapour pressures at 100°C : benzene 1350 mmHg; toluene 556 mmHg; p-xylene 240 mmHg.

4) The experimental data given below are for the *real* gas TMA at 273.2 K .

Pressure (atm) 0.2000 0.4000 0.6000 0.8000

Density (g/L) 0.5336 1.0790 1.6363 2.2054

a) Using the ideal gas law, calculate the molar mass of TMA at each pressure. (use 4 significant figures)

b) Which of the values obtained in part (a) is the best estimate of the molar mass of TMA? (use 4 significant figures) Briefly defend your choice.

c) What is your best estimate of the molar mass of TMA? (use 4 significant figures)

d) What is the compressibility (Z) of the gas at a pressure of 0.8000 atm? (use 4 significant figures)

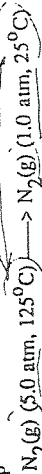
5) A gas stream which is 40.0 mole percent N_2 and 60.0 mole percent acetone is at 100 kPa and 70°C .

a) What is the percent saturation of the acetone in the gas stream?

b) To what temperature must the gas stream be cooled to condense 80.0% of the acetone? Assume that the total pressure remains constant at 100 kPa.

ΔH_v^0 of acetone at 56.0°C (its normal boiling point) is 30.2 kJ/mole .

6) 1.00 kg of N_2 ($C_p = 29.1 \text{ J/mol K}$) undergoes the change in state:



by expanding against a fixed external pressure of 1.0 atm. Assuming that N_2 behaves as an ideal gas and that C_p is independent of T , calculate:

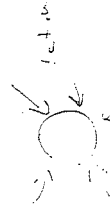
a) the change in the internal energy (ΔE) of the N_2 ,

b) the change in the enthalpy (ΔH) of the N_2 ,

c) the change in the entropy (ΔS) of the N_2 ,

d) the work done on the N_2 , and

e) the heat absorbed by the N_2 .





a) For the reaction at 298 K, calculate K_p and ΔS° .

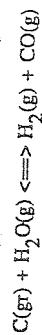
b) Is the sign of ΔS° obtained in part (a) what you would expect? Briefly explain.

c) Stating any assumptions made, determine the temperature at which the reaction becomes favourable under standard state conditions - i.e. the temperature at which $K_p = 1$.

At 298K

	$\Delta H_f^\circ (\text{kJ/mol})$	$\Delta G_f^\circ (\text{kJ/mol})$
$\text{H}_2\text{O}(\text{g})$	-241.8	-228.6
$\text{CH}_4(\text{g})$	-74.9	-50.8
$\text{CO}(\text{g})$	-110.5	-137.3

8) Steam is passed over a hot bed of C(gr) in a reactor maintained at 950K and the following equilibria are established:



$$K_p \text{ at } 950\text{K} = 1.25 \text{ atm}$$

$$K_p \text{ at } 950\text{K} = 1.60 \text{ atm}^{-1}$$

a) If 0.8 mol of $\text{H}_2(\text{g})$ are produced per mole of steam fed, calculate:

i) the number of moles of $\text{CO}_2(\text{g})$ produced per mole of steam fed, and

ii) the total pressure in the reactor at equilibrium.

b) Calculate K_p for the reaction $\text{C}(\text{gr}) + 2\text{H}_2\text{O}(\text{g}) \rightleftharpoons 2\text{H}_2(\text{g}) + \text{CO}_2(\text{g})$ at 950K.