

**Marks**  
**2**

- Calculate  $\Delta_r G^\circ$  for the reaction:  $2\text{N}_2\text{O}(\text{g}) + 3\text{O}_2(\text{g}) \rightarrow 4\text{NO}_2(\text{g})$
- Data:  $4\text{NO}(\text{g}) \rightarrow 2\text{N}_2\text{O}(\text{g}) + \text{O}_2(\text{g}) \quad \Delta_r G^\circ = -139.56 \text{ kJ mol}^{-1}$   
 $2\text{NO}(\text{g}) + \text{O}_2(\text{g}) \rightarrow 2\text{NO}_2(\text{g}) \quad \Delta_r G^\circ = -69.70 \text{ kJ mol}^{-1}$

Using  $\Delta_r G^\circ = \sum \Delta_f G^\circ(\text{products}) - \sum \Delta_f G^\circ(\text{reactants})$ , the free energy changes in the 3 reactions are, respectively:

$$(1) \Delta_r G^\circ = 4\Delta_f G^\circ(\text{NO}_2(\text{g})) - 2\Delta_f G^\circ(\text{N}_2\text{O}(\text{g}))$$

$$(2) \Delta_r G^\circ = 2\Delta_f G^\circ(\text{N}_2\text{O}(\text{g})) - 4\Delta_f G^\circ(\text{NO}(\text{g})) = -139.56 \text{ kJ mol}^{-1}$$

$$(3) \Delta_r G^\circ = 2\Delta_f G^\circ(\text{NO}_2(\text{g})) - 2\Delta_f G^\circ(\text{NO}(\text{g})) = -69.70 \text{ kJ mol}^{-1}$$

Taking  $2 \times (3) - (2)$  gives:

$$2 \times [2\Delta_f G^\circ(\text{NO}_2(\text{g})) - 2\Delta_f G^\circ(\text{NO}(\text{g}))] - [2\Delta_f G^\circ(\text{N}_2\text{O}(\text{g})) - 4\Delta_f G^\circ(\text{NO}(\text{g}))]$$

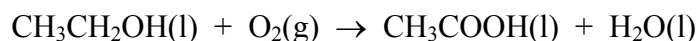
$$= (2 \times [-69.70] - [-139.56]) \text{ kJ mol}^{-1}$$

$$4\Delta_f G^\circ(\text{NO}_2(\text{g})) - 2\Delta_f G^\circ(\text{N}_2\text{O}(\text{g})) = +0.16 \text{ kJ mol}^{-1}$$

From above, this is equal to the  $\Delta_r G^\circ$  for reaction (1) as required.

Answer: **+0.16 kJ mol<sup>-1</sup>**

- Good wine will turn to vinegar if it is left exposed to air because the alcohol is oxidised to acetic acid. The equation for the reaction is:



Calculate  $\Delta_r S^\circ$  for this reaction in  $\text{J K}^{-1} \text{ mol}^{-1}$ .

Data:	$S^\circ (\text{J K}^{-1} \text{ mol}^{-1})$		$S^\circ (\text{J K}^{-1} \text{ mol}^{-1})$
$\text{C}_2\text{H}_5\text{OH}(\text{l})$	161	$\text{CH}_3\text{COOH}(\text{l})$	160.
$\text{O}_2(\text{g})$	205.0	$\text{H}_2\text{O}(\text{l})$	69.96

Using  $\Delta_r S^\circ = \sum S^\circ(\text{products}) - \sum \Delta S^\circ(\text{reactants})$ ,

$$\Delta_r S^\circ = [S^\circ(\text{CH}_3\text{COOH}(\text{l})) + S^\circ(\text{H}_2\text{O}(\text{l}))] - [S^\circ(\text{CH}_3\text{CH}_2\text{OH}(\text{l})) + S^\circ(\text{O}_2)]$$

$$= ([160. + 69.96] - [161 + 205.0]) \text{ J K}^{-1} \text{ mol}^{-1}$$

$$= -136 \text{ J K}^{-1} \text{ mol}^{-1}$$

Answer: **-136 J K<sup>-1</sup> mol<sup>-1</sup>**

**2**