Note: the following are examples of the type of calculations you may be asked to perform in the TE2 narrative paper. This is not a complete exam paper. Calculation questions typically make up 20 out of 40 marks for a paper.

EXAMPLE CALCULATIONS ASSOCIATED WITH THE MEASURMENT OF PHASE PARTITIONED SPECIES

Metals sampling - the following calculations are used in conjunction with BS EN 14385 and the associated Environment Agency Method Implementation Document (MID). Raw data from an assumed metals sampling scenario are provided in the tables below. Note that for the purpose of this example the results are for cadmium and thallium only.

General information

Gas Volume (m^3 at Ref conditions)	1.23 m^3
ELV (mg/m^3)	0.05 mg/m^3

Sample volumes

Filter digest and probe rinse volume (ml)	130 ml
Impinger 1 & 2 volume (ml)	240 ml
Impinger 3 volume (ml)	120 ml

Results

Mass of cadmium collected in filter digest and probe rinse	3 µg/l
Mass of cadmium in impinger 1 & 2	4 µg/l
Mass of cadmium in impinger 3	2 µg/l

Mass of thallium collected in filter digest and probe rinse	75 µg/l
Mass of thallium in impinger 1 & 2	91 µg/l
Mass of thallium in impinger 3	5 µg/l

To determine if the absorbers meet the quality assurance requirements stated in the standard method BS EN 14385

1. To calculate the absorber efficiencies

1.1 Calculate the absorber efficiency for cadmium

Mass of Cd collected on filter and probe = 3 μg/l
Filter digest and probe rinse sample volume = 130 ml
(1 Litre = 1000 ml)

Mass of Cd collected in probe & filter

$$= \frac{\text{sample volume}}{1000\ \text{ml}} \times \text{concentration of Cd in sample}$$

$$= \frac{130\ \text{ml}}{1000\ \text{ml}} \times 3\ \mu\text{g/l}$$

= 0.39 μg (Note: divide by 1 x 1000 to convert the result from μg to mg)

= 0.00039 mg

Mass of Cd collected in impingers 1 and 2 = 4 μg/l
Impinger 1 and 2 sample volume = 240 ml
(1 Litre = 1000 ml)

Mass of Cd collected in impingers 1 and 2

$$= \frac{\text{sample volume}}{1000\ \text{ml}} \times \text{concentration of Cd in sample}$$

$$= \frac{240\ \text{ml}}{1000\ \text{ml}} \times 4\ \mu\text{g/l}$$

= 0.96 μg (Note: divide by 1 x 1000 to convert the result from μg to mg)

= 0.00096 mg

Mass of Cd collected in impinger 3 = 2 μg/l
Impinger 3 sample volume = 120 ml
(1 Litre = 1000 ml)

Mass of Cd collected in impinger 3

$$= \frac{\text{sample volume}}{1000\ \text{ml}} \times \text{concentration of Cd in sample}$$

$$= \frac{120\ \text{ml}}{1000\ \text{ml}} \times 2\ \mu\text{g/l}$$

= 0.24 μg (Note: divide by 1 x 1000 to convert the result from μg to mg)

= 0.00024 mg

Total mass of Cd collected = mass of Cd collected in filter digest and probe rinse +
mass of Cd collected in impingers 1 and 2 +
mass of Cd collected in impinger 3

= 0.00039 mg + 0.00096 mg + 0.00024 mg

= 0.00159 mg

Percentage of mass absorbed by impinger 3 $= \frac{\text{mass collected in impinger 3}}{\text{total mass collected}} \times 100$

$$= \frac{0.00024\ \text{mg}}{0.00159\ \text{mg}} \times 100$$

= 15.1%

Absorber efficiency = 100% - percentage of mass absorbed by impinger 3

= 100% - 15.1%

= 84.9%

1.2 Calculate the absorber efficiency for thallium

Mass of Tl collected in filter and probe = 75 μg/l
Probe rinse and filter sample volume = 130 ml
(1 Litre = 1000 ml)

Mass of Tl collected in probe & filter

$$= \frac{\text{sample volume}}{1000\ \text{ml}} \times \text{concentration of Tl in sample}$$

$$= \frac{130\ \text{ml}}{1000\ \text{ml}} \times 75\ \mu\text{g/l}$$

= 9.75 μg (Note: divide by 1 x 1000 to convert the result from μg to mg)

= 0.00975 mg

Mass of Tl collected in impingers 1 and 2 = 91 μg/l
Impinger 1 and 2 sample volume = 240 ml
1 Litre = 1000 ml

Mass of Tl collected in impingers 1 and 2

$$= \frac{\text{sample volume}}{1000\ \text{ml}} \times \text{concentration of Tl in sample}$$

$$= \frac{240\ \text{ml}}{1000\ \text{ml}} \times 91\ \mu\text{g/l}$$

= 21.84 μg (Note: divide by 1000 to convert the result from μg to mg)

= 0.02184 mg

Mass of Tl collected in impinger 3 = 5 μg/l
Impinger 3 sample volume = 120 ml
1 Litre = 1000 ml

Mass of Tl collected in impinger 3

$$= \frac{\text{sample volume}}{1000\ \text{ml}} \times \text{concentration of Tl in sample}$$

$$= \frac{120\ \text{m}}{1000\ \text{ml}} \times 5\ \mu\text{g/l}$$

= 0.6 μg (Note: divide by 1 x 10^3 to convert the result from μg to mg)

= 0.0006 mg

Total mass of Tl collected = mass of Tl collected in filter digest and probe rinse + mass of Tl collected in impingers 1 and 2 + mass of Tl collected in impinger 3

= 0.00975 mg + 0.02184 mg + 0.0006 mg

= 0.03219 mg

Percentage of mass absorbed by impinger 3 = $\frac{\text{mass collected in impinger 3}}{\text{total mass collected}} \times 100$

= $\frac{0.0006 \text{ mg}}{0.03219 \text{ mg}} \times 100$

= 1.9%

Absorber efficiency = 100% - percentage of mass absorbed by impinger 3

= 100% - 1.9%

= 98.1%

2. To determine if the absorber quality assurance requirements apply

2.1 Calculate the total concentration, of cadmium and thallium combined, in mg/m^3

Total mass of Cd collected = 0.00159 mg
Total mass of Tl collected = 0.03219 mg
Gas volume sampled at reference conditions = 1.23 m^3

$$\text{Concentration} = \frac{1\text{m}^3}{\text{gas volume sampled}} \times (\text{mass of Cd} + \text{mass of Tl})$$

$$= \frac{1\ \text{m}^3}{1.23\ \text{m}^3} \times (0.00159\ \text{mg} + 0.03219\ \text{mg})$$

$$= 0.0275\ \text{mg/m}^3$$

2.2 Calculate the concentration of the combined result as a percentage of the ELV

ELV = 0.05 mg/m^3

Combined result of Cd and Tl = 0.0275 mg/m^3

$$\text{Combined result as a percentage of the ELV} = \frac{\text{combined result}}{\text{ELV}} \times 100$$

$$= \frac{0.0275\ \text{mg/m}^3}{0.05\ \text{mg/m}^3} \times 100$$

$$= 55\%$$

3. To determine if the absorber quality assurance requirements apply to the individual elements

3.1 Calculate the mass of cadmium as a percentage of the combined masses of both cadmium and thallium

Total mass of Cd collected = 0.00159 mg
Total mass of Tl collected = 0.03219 mg

$$\text{Combined mass of Cd and Tl} = \text{mass of Cd collected} + \text{mass of Tl collected}$$

$$= 0.00159\ \text{mg} + 0.03219\ \text{mg}$$

$$= 0.03378\ \text{mg}$$

$$\text{Percentage of Cd collected} = \frac{\text{mass of Cd collected}}{\text{combined mass of Cd and Tl}} \times 100$$

$$= \frac{0.00159\ \text{mg}}{0.03378\ \text{mg}} \times 100$$

$$= 4.7\%$$

3.2 Calculate the mass of thallium as a percentage of the combined masses of both cadmium and thallium

Total mass of Tl collected = 0.03219 mg
Combined mass of Cd and Tl = 0.03378 mg

$$\text{Percentage of Tl collected} = \frac{\text{mass of Tl collected}}{\text{combined mass of Cd and Tl}} \times 100$$

$$= \frac{0.03219 \text{ mg}}{0.03378 \text{ mg}} \times 100$$

$$= 95.3\%$$

4. Assessing the results

4.1 BS EN 14385 and the MID places requirements on the absorber efficiency that must be met in order to show that a result is valid. Use these requirements to show if the above results are valid.

The total result for cadmium and thallium combined is over 30% of the ELV, which means the absorber efficiency quality assurance check must be met. Cadmium has a percentage absorber efficiency of 85%, so does not meet the 90% absorber efficiency requirement. Cadmium makes up more than 1% of the total mass. The result for cadmium is therefore not in compliance with the MID for EN 14385.

Dioxin Sampling

The following calculations are used in conjunction with method BS EN 1948 and the associated Environment Agency Method Implementation Document (MID). Data from an assumed dioxin sampling scenario are provided in the tables below. Note that for the purpose of this example the results of only three dioxin congeners have been included.

Duct and reference conditions

	Duct	Reference
Oxygen concentration	14% (dry)	11%
Moisture content	11.5%	Dry

General information

Gas volume sampled (STP, wet)	5 m^3
Nozzle size	5.5 mm
Isokinetic rate	93%
ELV	0.1 ng/m^3

Dioxin results

Congeners	Dioxin result	I-TEF
2,3,7,8-TCD	68 pg	1
1,2,3,7,8-PeDD	204 pg	0.5
1,2,3,7,8,9-HxCDD	89 pg	0.1
Blank value		0.0024 ng

5. Calculate the dioxin sample concentration in ng/m^3

5.1 Calculate the I-TEQ for each congener in ng/m^3

I-TEQ of the 2,3,7,8-TCD congener

= dioxin result x ITEF

= $\frac{68 \text{ pg}}{1000}$ x 1 (Note: divide by 1000 to convert the result from pg to ng)

= 0.068 ng

I-TEQ of the 1,2,3,7,8-PeDD congener

= dioxin result x ITEF

= $\frac{204 \text{ pg}}{1000}$ x 0.5 (Note: divide by 1 x 1000 to convert the result from pg to ng)

= 0.102 ng

I-TEQ of the 1,2,3,7,8,9-HxCDD congener

= dioxin result x ITEF

= $\frac{89 \text{ pg}}{1000}$ x 0.1 (Note: divide by 1 x 1000 to convert the result from pg to ng)

= 0.009 ng

5.2 To calculate the total mass of the 3 congeners

Total mass = mass of congener 1 + mass of congener 2 + mass of congener 3

= 0.068 ng + 0.102 ng + 0.009 ng

= 0.179 ng

5.3 To calculate the concentration of the total mass of congeners to reference conditions (STP, 11% oxygen, dry)

Gas volume sample (wet) = 5 Nm^3
Total mass of congeners = 0.179 ng

Concentration of congeners in ng/m^3 = $\frac{\text{mass of congeners}}{\text{gas volume sample}}$

= $\frac{0.179\ ng}{5\ m^3}$

= 0.036 ng/Nm^3

Moisture correction factor = $\frac{100}{(100 - \text{stack moisture})}$

= $\frac{100}{(100 - 11.5)}$

= 1.13

Oxygen correction factor = $\frac{(21 - \text{reference oxygen})}{(21 - \text{stack oxygen})}$

= $\frac{(21 - 11)}{(21 - 14)}$

= 1.43

Concentration of congeners in ng/m^3 at reference conditions

= concentration x moisture factor x oxygen factor

= 0.036 ng/Nm^3 x 1.13 x 1.43

= 0.058 ng/m^3

6. Evaluate the sampling against the requirements of standard BS EN 1948 and the associated MID.

6.1 To calculate the blank concentration value in ng/m3 at reference conditions (STP, 11% oxygen, dry)

Mass of blank = 0.0024 ng
Gas volume sample = 5 m^3
Moisture correction factor = 1.13
Oxygen correction factor = 1.43

Blank concentration value in ng/m^3 = $\frac{\text{mass of blank}}{\text{gas volume sample}}$

= $\frac{0.0024 \text{ ng}}{5 \text{ m}^3}$

= 0.0005 ng/m^3

Blank concentration value in ng/m^3 at reference conditions

= blank value concentration x moisture factor x oxygen factor

= 0.0005 ng/m^3 x 1.13 x 1.43

= 0.0008 ng/m^3

6.2 Blank value

Blank concentration value at reference conditions = 0.0008 ng/m^3
ELV = 0.1 ng/m^3

10% of the ELV = $\frac{0.1 \text{ ng/m}^3}{10}$ = 0.01 ng/m^3

The blank value is less than 10% of the ELV and therefore meets the requirements of the standard.

6.3 Nozzle size

The nozzle size used for the sampling was 5.5mm. The standard states that nozzles of less than 6mm should be avoided. The nozzle size did not meet this requirement.

6.4 Percentage isokinetic rate

The percentage isokinetic rate of the sampling was 93%. The standard requires a rate of 95% to 115%. The sampling did not meet this requirement.